How expertise and motivation affect the recognition of own- and other-race faces: Behavioural and electrophysiological evidence

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Simone C. Tüttenberg

Humans have difficulties recognising other-race faces, and this own-race bias (ORB) has been explained in terms of either reduced perceptual expertise with other-race faces or socio-cognitive and motivational factors, such as categorisation of other-race faces into social out-groups. The aim of this thesis was to investigate the role of these factors to the ORB using behavioural and event-related brain potential (ERP) measures. First, it was investigated whether increasing motivation to individuate other-race faces can reduce or even eliminate the ORB in recognition memory. Chapter 2 revealed that a modulation of face memory by motivational factors is possible, but restricted to face categories for which participants have acquired expertise. In Chapter 3, instructions to individuate and closely attend to other-race faces during learning reduced the ORB, but ERPs recorded during encoding indicated that additional effort was required to overcome difficulties associated with other-race face recognition. Second, it was examined whether own- and other-race faces are learnt equally well from highly variable images in paradigms that encourage individuation of own- and other-race identities. Chapter 4 revealed better learning for own- relative to other-race identities, and only extensive other-race contact eliminated this own-race advantage. In Chapter 5, ERP results indicated that the own-race advantage in identity learning resulted from facilitated processing of own-race faces at an early perceptual level. In sum, the present research suggests that the ORB is mainly driven by differential perceptual expertise. However, motivational factors can modulate the effect when participants have acquired sufficient expertise with a given face category and thus the present results offer novel insights into how expertise and motivation interact.

How expertise and motivation affect the recognition of own- and other-race faces:

Behavioural and electrophysiological evidence

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Thesis submitted for the degree of Doctor of Philosophy

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February 2019

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Declaration

I confirm that no part of the material presented in this thesis has previously been submitted by me for a degree in this or in any other institution. If material has been generated through joint work, this has been indicated where appropriate. All other sources have been referenced, and quotations suitably indicated.

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February 2019

Publication note

Chapter 2: Tüttenberg, S. C., & Wiese, H. (under review). Intentionally remembering or forgetting own- and other-race faces: Evidence from directed forgetting.

Chapter 4: Tüttenberg, S. C., & Wiese, H. (in revision). Learning own- and other-race facial identities from natural variability.

Chapter 5: Tüttenberg, S. C., & Wiese, H. (under review). Learning own- and other-race facial identities: Evidence from event-related brain potentials.

The experiment reported in Chapter 5 was presented at the European Conference of Visual Perception 2017.

Statement of Copyright

Acknowledgements

To my supervisor, Dr Holger Wiese, a sincere thank you for your continuous support and guidance, for your help and expertise, and for always having an open ear for my ideas and concerns. It has been an invaluable experience to work with you on this project.

To Holger and all other researchers from the Person Perception Unit at Jena University, thank you for being so enthusiastic about face research and for sparking my interest in the topic.

To Dr Anna Grubert, thank you for giving critical feedback whenever I gave a talk and for always offering support.

To all the students who have worked in the EEG lab over the last three years, thank you for your help with recruiting participants and preparing them for EEG recording.

To my sister, thank you for taking good care of our family when I am not around and for always keeping me informed about what is going on at home.

To my parents, thank you for your support throughout my studies. I would not have been able to do this without your help and encouragement.

1 Introduction

Humans are often considered to be “face experts”. We are able to remember and recognise an impressive amount of faces that we encounter throughout our lifetime, seemingly without effort. This is a remarkable ability given that a particular face may never appear in the exact same way more than once and that faces as a category in general are very similar, in particular with respect to their configuration. However, not all faces are recognised equally well and more recently, it has been suggested that our face expertise is in fact far more restricted that we might think (Young & Burton, 2018).

One of the most widely researched phenomena in the face recognition literature is the own-race bias (ORB, also often referred to as other-race effect), the finding that people are better at remembering faces belonging to their own race compared to faces from a different ethnicity (Meissner & Brigham, 2001). Yet there is still considerable debate with regard to the mechanisms underlying the ORB.

In addition to these well-documented difficulties recognising other-race faces, a more general problem may be that of unfamiliar face recognition per se. It is becoming increasingly clear that while we can effortlessly recognise a familiar face, unfamiliar face recognition is much more difficult. Over the last few years, a substantial amount of research effort has been put into investigating how unfamiliar faces become familiar but our understanding of this process remains incomplete. At the same time, only very little research has so far investigated differences in own- and other-race face learning which may arguably be a fruitful way to improve our understanding of the ORB.

In general, difficulties recognising people may not only lead to awkward situations during social encounters but, more importantly, can also have severe consequences for person identification in security and legal contexts (e.g., passport control, CCTV, eyewitness testimony) where the failure to correctly recognise someone can potentially lead to wrongful convictions of innocent individuals. While this may generally apply to all unfamiliar faces, it might pose an even bigger challenge for unfamiliar other-race faces.

1.1 The own-race bias

The ORB was first described by Feingold in 1914 who noted that

> "individuals of a given race are indistinguishable from each other in proportion to our familiarity, to our contact with the race as a whole. Thus to the uninitiated American, all Asiatics look alike, while to the Asiatic all white men look alike. I admit that the identification of a foreigner in the same environment in which, not he, but a member of his race had been seen before, might result in false recognition. But this is possible under any circumstances, since it is due to incomplete perception of distinctive qualities." (Feingold, 1914, p. 50)

Malpass and Kravitz (1969), aware of the potential implications of an ORB for person identification in both social and legal contexts, conducted the first systematic investigation of ethnicity-related difficulties in the recognition of own- and other-race faces in White and Black subjects. Participants were presented with own- and other-race faces in an initial study phase and asked to remember them. Subsequently, at test, participants had to make old/new decisions to "old" faces that had been presented during the study phase and "new" faces that had not previously been presented. The authors provided the very first empirical demonstration of an ORB in face recognition memory and, as already proposed by Feingold (1914), interpreted this finding to reflect differential experience with people from different ethnic groups. Since then, the ORB has been replicated numerous times, in different samples and with stimuli from various ethnicities. For example, the ORB has been investigated with Caucasian and (East) Asian faces in Caucasian and/or (East) Asian participants in different countries, such as Germany, Belgium, Australia, and China (e.g., Herzmann, Willenbockel, Tanaka, & Curran, 2011; Michel, Caldara, & Rossion, 2006; Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2004; Wan, Crookes, Reynolds, Irons, & McKone, 2015; Wiese, Kaufmann, & Schweinberger, 2014; Zhao, Hayward, & Bülthoff, 2014); with Caucasian and Egyptian faces in Caucasian and Egyptian participants (e.g., Megreya, White, & Burton, 2011); with Israeli and East Asian faces in Israeli and East Asian participants (e.g., Zhao & Bentin, 2008); with Black and White faces in White participants (e.g., Ackerman et al., 2006; Hehman, Stanley, Gaertner, & Simons, 2011; Ito, Thompson, & Cacioppo, 2004; Meissner, Brigham, & Butz, 2005; Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008); or with Black and White South African faces in Black and White South African participants (e.g., Chiroro, Tredoux, Radaelli, & Meissner, 2008). The ORB has also been confirmed in a number of review articles and meta-analyses (e.g., Anthony, Copper, & Mullen, 1992; Bothwell, Brigham, & Malpass, 1989; Chance & Goldstein, 1996; Meissner & Brigham, 2001; Shapiro & Penrod, 1986). The most recent and comprehensive one (Meissner & Brigham, 2001) included roughly 40 research articles with more than 90 independent samples and nearly 5,000 participants and suggests that the ORB is a robust and consistent finding.

1.2 Theoretical accounts of the ORB

Over the past 50 years, different theoretical accounts have been put forward to explain the ORB. At their core, these approaches either emphasise long-term perceptual expertise with a given class of faces or, alternatively, stress the importance of socio-cognitive and motivational aspects. Some exemplary accounts of the ORB along with supporting evidence are discussed below. A more expansive overview of the potential mechanisms underlying the ORB can be found in Meissner and Brigham (2001).

1.2.1 Perceptual expertise accounts

Perceptual expertise accounts are based on the fundamental idea that face processing is optimised for the faces we have encountered throughout our lifetime (e.g., Chiroro & Valentine, 1995). Given that most people live in ethnically homogenous environments and have only limited contact with people from different ethnic groups, face processing is often finely tuned to own-race faces. Perceptual expertise accounts either highlight difficulties during the perceptual processing of other-race faces or assume that these faces are represented less well in memory.

Processing accounts

Other-race faces are often considered to be processed less efficiently at a perceptual, i.e., configural and/or holistic, level which may impair subsequent recognition of other-race faces (e.g., Hayward, Crookes, & Rhodes, 2013; Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010; Rhodes, Brake, Taylor, & Tan, 1989; Rhodes, Ewing, et al., 2009; Rhodes, Hayward, & Winkler, 2006; but see

Zhao et al., 2014). Configural and holistic processing reflect the ability of the visual system to process the metric differences between face features (e.g., mouth, nose, eyes) and their integration into a Gestalt-like representation (Maurer, Le Grand, & Mondloch, 2002).

One of the findings taken to support reduced configural/holistic processing is that other-race faces are less affected by inversion than own-race faces (Hancock & Rhodes, 2008; Rhodes et al., 1989; Sangrigoli & de Schonen, 2004; but see Valentine & Bruce, 1986). Face inversion (a picture-plane rotation by 180° resulting in faces being presented upside-down; Yin, 1969) is thought to disrupt configural and/or holistic processes, and reduced inversion effects for other-race faces have been interpreted to indicate less configural/holistic processing for other-race faces. However, inversion effects have been criticised for providing a rather indirect measure of configural processing as the configuration of the face itself remains unaltered (see e.g., Hayward et al., 2013; Michel, Caldara, et al., 2006).

Two commonly employed tasks to more directly measure holistic processing are the composite face task (Young, Hellawell, & Hay, 1987) and the part whole task (Tanaka & Farah, 1993). In the original version of the former (Young et al., 1987), participants are required to identify a familiar person from the top (or bottom) half of a face that is either aligned (i.e., creating a so-called composite face) or misaligned (i.e., lower half is slightly offset horizontally to the left or right) with the bottom (or top) half of a different face. The identification of a face is impaired in the aligned compared to the misaligned condition. Hole (1994) introduced a different version of the composite face task, in which participants complete a delayed matching task and have to decide whether the upper halves of two faces presented in succession are identical or not, which, unlike the version by Young et al. (1987), can also be applied to unfamiliar faces. Critically, in this version, the task-irrelevant lower half of the second face is always different. Participants are slower and less accurate to make “same” judgements when top and bottom half of the second stimulus are aligned than when the two halves are misaligned. The processing disadvantage in the aligned condition is interpreted to reflect holistic processing. This composite effect is sometimes found to be larger for own-relative to other-race faces (Michel, Rossion, et al., 2006; but see Bukach, Cottle, Ubiwa, & Miller, 2012; Hayward, Crookes, Chu, Favelle, & Rhodes, 2016; Mondloch et al., 2010). By contrast, in the part whole task, a target face is presented and subsequently, a given facial feature (e.g., the eyes) has to be recognised either in the context of a face (whole condition) or when presented in isolation (part condition). Participants are usually better at recognising a given facial feature in the context of a whole face than when it is presented on its own, the so-called whole/part advantage. This whole/part advantage is often found for own- but not other-race faces in Caucasian, but not necessarily in East Asian participants (Crookes, Favelle, & Hayward, 2013; Michel, Caldara, et al., 2006; Mondloch et al., 2010; Tanaka et al., 2004).

As can be seen, the results are quite mixed (for a more detailed discussion, see Hayward et al., 2013, 2016). In addition, these measures are sometimes found to predict the ORB in memory (Hancock & Rhodes, 2008; Rhodes, Ewing, et al., 2009), but sometimes not (Michel, Caldara, et al., 2006; Michel, Rossion, et al., 2006). Although race was not taken into account, recent work provided empirical evidence that the three tasks commonly used to measure configural and/or holistic processing (i.e., inversion, composite face task, part whole task) are, if anything, only weakly correlated with face recognition performance (Rezlescu, Susilo, Wilmer, & Caramazza, 2017). More generally, the concepts of configural and/or holistic processing have been criticised for being poorly defined, and their role for face recognition has been questioned (e.g., Burton, 2013; Burton, Schweinberger, Jenkins, & Kaufmann, 2015).

Representational accounts

An exemplary expertise-based account of the ORB that emphasises how faces are represented in memory is the multidimensional face-space account (MDFS; Valentine, 1991; Valentine & Endo, 1992; Valentine, Lewis, & Hills, 2016). Apart from accounting for the effects of race, MDFS also offers an intuitive account of a number of face recognition phenomena, such as inversion and distinctiveness effects (e.g., Benson & Perrett, 1994; Lee, Byatt, & Rhodes, 2000; Lewis & Johnston, 1998). MDFS constitutes a psychological similarity space consisting of multiple dimensions along which each face is encoded. These dimensions code certain features or sets of features. As they evolve through perceptual learning, they are optimal to distinguish between the faces a person commonly encounters. Given that most people have predominant contact with own-race faces, the dimensions of one's face space are ideally suited to discriminate between faces of one's own race. In contrast, the dimensions of MDFS are poorly suited to code faces of a different race one is substantially less familiar with (see e.g., Hills & Lewis, 2006, 2011). In consequence, other-race faces are more densely clustered in MDFS than own-race faces (see e.g., Byatt & Rhodes, 2004; Caldara & Abdi, 2006; Papesh & Goldinger, 2010), resulting in less accurate recognition of other- relative to own-race faces.

While MDFS can accommodate a large number of findings in the face memory literature, it has been criticised that the exact number and nature of dimensions of MDFS are often not clearly specified (but see Calder, Burton, Miller, Young, & Akamatsu, 2001). Illustrations of MDFS often depict a very limited number of dimensions (i.e., rarely more than two or three) and it has been shown that conceptualisations derived from such a limited number are not always accurate if one assumes a space with a sufficiently large number of dimensions to accurately represent individual faces (Burton & Vokey, 1998).

In addition, it might be that the conceptualisation of a given face being stored as a point in MDFS is in fact oversimplified (but see Tanaka, Giles, Kremen, & Simon, 1998, for a different approach using “attractor fields”) in light of more recent evidence that reveals the sheer scale of variability of a particular face (for a review, see e.g., Burton, Jenkins, & Schweinberger, 2011). This is discussed in more detail below.

Evidence for perceptual expertise accounts

In support of a perceptual expertise account, the ORB in recognition memory is often found to decrease as the amount of contact with other-race people increases (e.g., Hancock & Rhodes, 2008; Wan et al., 2015; Wiese et al., 2014; Young & Hugenberg, 2012; Zhao et al., 2014). Recently, it has also been shown that although participants reported having put more effort into individuating other-race faces, this increased effort did not attenuate the ORB (Crookes & Rhodes, 2017; Wan et al., 2015). Similarly, instructing participants to put more effort into individuating other-race faces and to pay particular attention to them has been reported to increase the time allocated to studying other-race faces (Tullis, Benjamin, & Liu, 2014), but did not successfully reduce the ORB (Bornstein, Laub, Meissner, & Susa, 2013; Tullis et al., 2014; Wan et al., 2015). This is in line with the suggestion that only experience acquired over a long time can affect the ORB.

Moreover, extensive experience with other-race faces has been shown to improve recognition memory for this face category. For instance, Asian children that were adopted by European families at an early age show no or even a reversed ORB (de Heering, de Liedekerke, Deboni, & Rossion, 2010; Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005).

More recent evidence for a perceptual expertise-based account of the ORB comes from studies showing difficulties with other-race faces at a perceptual level, for example when identity has to be established across multiple, highly variable images (e.g., Laurence, Zhou, & Mondloch, 2016; Yan, Andrews, Jenkins, & Young, 2016). Difficulties with other-race faces are also apparent in learning paradigms where participants are trained with a subset of images and later on have to recognise these faces from previously unseen images (e.g., Hayward, Favelle, Oxner, Chu, & Lam, 2017; Zhou, Matthews, Baker, & Mondloch, 2018). These paradigms and findings will be described in more detail below.

1.2.2 Socio-cognitive accounts

Socio-cognitive theories assume that faces are initially categorised as belonging to a social in- or out-group, for example, but not exclusively, with respect to race. This categorisation then decides about how these faces are subsequently processed.

Race-feature hypothesis

Levin (1996, 2000) proposed that the ORB results from the selection of race-specifying information in other-race faces. More specifically, once a feature is detected in a given face that is characteristic of a racial out-group, processing of this face is mostly restricted to this race-specifying information. Own-race faces, in contrast, are processed at an individual level, resulting in better recognition of own- relative to other-race faces. Importantly, the race-feature hypothesis (Levin, 1996, 2000) holds that the ORB arises because the attentional focus on category information extracted from other-race faces is not optimal for recognition, and not because of a lack of perceptual expertise with the other-race category. The coding of race-specifying information as a visual feature in other-race faces, despite not being helpful for recognition, facilitates the detection of, and search for, other-race faces (Levin, 1996, 2000). Therefore, when required to categorise faces according to race, people are generally faster to do so for other-race compared to own-race faces (for empirical evidence, see e.g., Ge et al., 2009; Zhao & Bentin, 2008).

In-group/Out-group model

The in-group/out-group model of face processing (Sporer, 2001) proposes that at the initial encounter, a face is automatically categorised as either in- or out-group based on a specific facial feature, such as hair colour, skin tone, or a facial configuration characteristic of a particular group. Following this categorisation, in-group faces are processed in a "default" manner encouraging further processing of these faces that, as a consequence, enables later recognition. In contrast, faces categorised as out-group are thought to trigger more shallow encoding (see Craik & Lockhart, 1972) or processes that direct attention away from the particular face (e.g., cognitive disregard, see Rodin, 1987), which in turn reduces recognition accuracy for out-group relative to in-group faces.

Categorization – Individuation Model

Socio-cognitive models of the ORB, or own-group biases more generally, all propose that faces are initially categorised as belonging to a social in- or out-group and following this categorisation, faces are either processed in a categorical or individual manner. Hugenberg and colleagues proposed the Categorization – Individuation Model (CIM; Hugenberg, Young, Bernstein, & Sacco, 2010) that incorporates three factors; social categorisation, perceiver motivation and perceiver experience (for a more recent extension on group biases that are potentially related to the ORB, see Hugenberg, Wilson, See, & Young, 2013). Similar to the socio-cognitive models outlined above, social categorisation refers to a default categorisation of faces into in- or out-groups. However, at variance with these models, the CIM suggests that perceiver motivation can modulate this initial categorisation and direct attention to either category- or identity-related information. In particular, situational cues may serve to redirect attention to individuating features in out-group faces when these become relevant or important, which should in turn increase memory (see e.g., Ackerman et al., 2006; Hugenberg, Miller, & Claypool, 2007; Young & Hugenberg, 2012). In addition, the CIM posits that prior experience with other-race faces may help guide perceivers' attention to those dimensions that are suited best to discriminate between different other-race faces. However, it should be noted that perceptual experience plays a comparatively minor role in this model as the extent to which expertise is employed depends on motivation. Specifically, expertise only becomes fully effective when perceivers are sufficiently motivated to individuate the faces at hand.

Evidence for socio-cognitive accounts

Socio-cognitive models receive support from findings showing that memory effects similar to the ORB can be detected for purely social face categories which do not differ with respect to expertise. For example, it has been shown that participants demonstrate better memory for faces of people they are led to believe attend the same university as them compared to faces of people supposedly attending a different university (Bernstein, Young, & Hugenberg, 2007). Likewise, better memory for in- compared to out-group faces has also been observed for arbitrary groups created within the experimental session, such as randomly assigning participants to a “red or green personality type” (Bernstein et al., 2007; Short & Mondloch, 2010; Young, Bernstein, & Hugenberg, 2010). In addition, the ORB in memory can be overridden when a purely social dimension is made salient (Cassidy, Quinn, & Humphreys, 2011; Hehman, Mania, & Gaertner, 2010). In these studies, participants showed better memory for own- compared to other-university faces when own- and other-race faces were grouped according to university affiliation during learning.

Moreover, stereotypic features added to racially ambiguous faces strongly influence performance on a recognition memory test. Latino participants showed superior recognition memory performance for ambiguous faces with added stereotypic Latino hairstyles than for the same ambiguous faces with added stereotypic Black hairstyles (MacLin & Malpass, 2001, 2003; see also Hourihan, Fraundorf, & Benjamin, 2013). Similarly, larger composite effects were observed for purely social in- compared to out-group faces (Hugenberg & Corneille, 2009) as well as when ambiguous faces were categorised as own-race faces than when the same faces were categorised as other-race faces (Michel, Corneille, & Rossion, 2007, 2010).

Further support for socio-cognitive accounts comes from studies showing that the ORB can be eliminated when participants are informed about the ORB prior to taking part in the experiment, and are additionally asked to put more effort into individuating other-race faces and to attend to individuating features in them (Hugenberg et al., 2007; Rhodes, Locke, Ewing, & Evangelista, 2009; Young et al., 2010; Young & Hugenberg, 2012). This suggests that the ORB results from a failure to encode other-race faces in sufficient detail, and that explicitly instructing participants to focus on other-race faces during learning encourages individuation of other-race faces, which improves recognition for this face category.

In addition, own- and other-race face recognition can be modulated by social group membership and social context. For example, Shriver and colleagues found that own-race faces categorised as belonging to a social out-group (i.e., putatively attending a different university) are recognised less well than own-race faces perceived as in-group (Shriver et al., 2008). Furthermore, middle-class participants showed reduced recognition of own-race faces presented on impoverished backgrounds indicative of a socio-economic out-group compared to own-race faces presented on backgrounds that imply wealth (Shriver et al., 2008). Moreover, a significant increase in other-race face recognition has been reported when these are perceived as threatening, which substantially reduced the ORB (Ackerman et al., 2006; Shriver & Hugenberg, 2010).

Of note, while many of these findings support a socio-cognitive explanation of the ORB more generally, the findings discussed in the previous two paragraphs specifically support the CIM (Hugenberg et al., 2010) as they show that the default processing of own- and other-race faces can be overridden by situational cues and/or perceiver motives. On the one hand, the default processing of own-race faces at a detailed, individuating level can be superseded when situational aspects or some other cue are perceived to be incongruent with the in-group status (Shriver et al., 2008). On the other hand, when contextual aspects and/or perceiver motives suggest that other-race faces may be important or relevant (Ackerman et al., 2006; Hugenberg et al., 2007; Shriver & Hugenberg, 2010), this may encourage participants to individuate them, thereby increasing recognition memory for other-race faces.

1.2.3 Towards a dual-route approach of the ORB

The perceptual expertise accounts of the ORB outlined above have been discussed somewhat critically. By contrast, a comparable discussion has not been undertaken for the exemplary socio-cognitive models. However, this is not to say that these models have not been criticised. In fact, some of the findings and/or interpretations described in the previous section were not confirmed by other researchers who used highly similar, if not identical, designs (own-group bias: Short & Mondloch, 2010; no ORB when faces are grouped according to university affiliation: Kloth, Shields, & Rhodes, 2014; stronger holistic processing of social in-group faces: Sadozai, Kempen, Tredoux, & Robbins, 2018; individuating instructions eliminate ORB: Bornstein et al., 2013; Rhodes et al., 2009; Tullis et al., 2014; Wan et al., 2015; no ORB for angry faces: Gwinn, Barden, & Judd, 2015). On the whole, these findings provide limited evidence for a socio-cognitive or motivational account of the ORB and are more in line with a perceptual expertise account.

While the CIM was the first model to acknowledge that the ORB might be driven by both socio-cognitive and expertise-related factors, it, as discussed above, is arguably still predominantly socio-cognitive or motivational in nature. More recently, Wan et al. (2015) have proposed a dual-route approach whereby both expertise and motivation may contribute to the ORB. Importantly, the relative contribution of expertise and motivation is thought to depend on the cultural setting in which the ORB is investigated. Specifically, the authors observed a strong ORB in Australia testing White Australian and Asian participants and concluded that in this setting, the ORB was unaffected by motivation and resulted entirely from differential expertise. This is contrary to what is often found in the US when African American and European American participants are tested, and where the ORB is predominantly driven by socio-cognitive factors. The authors argued that depending on the setting in which it is investigated (most directly with respect to the socio-economic status of the racial groups), the ORB can have different causes. More generally, Wan et al. (2015) suggest that models that rely on a single mechanism (e.g., Levin, 1996; 2000; Sporer, 2001) may be oversimplified and may not fully capture the problem of other-race face recognition. At the same time, although the idea put forward by Wan et al. (2015) seems to be a fruitful approach to understanding the ORB and may, at least in part, reconcile discrepant findings, more research is clearly needed to more fully understand the contribution of both expertise and motivational or attentional factors in a respective cultural setting.

1.3 Unfamiliar face recognition

The ORB is most commonly investigated in old/new recognition memory paradigms in which participants are required to learn images of unfamiliar own- and other-race faces during an initial study phase. Subsequently during the test phase, participants have to recognise these learnt images among new images that have not been presented before. The ORB is evident in higher hit rates, higher correct rejection rates and/or higher sensitivity (*d';* Wickens, 2002) for own- relative to other-race faces. As the same image of a face is presented during learning *and* at test, this paradigm has been suggested to actually assess *image* recognition rather than *face* recognition (e.g., Burton, 2013). Although some studies used different images during learning and at test which differed e.g., with respect to viewpoint or facial expression (Bornstein et al., 2013; Chiroro & Valentine, 1995; Gwinn et al., 2015), such studies also arguably fail to capture important aspects of *face* recognition. Importantly, as described in more detail below, the problem of face vs. image recognition applies to face recognition in general and is not restricted to the ORB. Difficulties recognising unfamiliar (own-race) faces across different photographs are well known, and over the last couple of years, it has become clear that variability of an individual face needs to be studied as it may help understand the key differences between familiar and unfamiliar face recognition (e.g., Burton, 2013; Jenkins & Burton, 2011).

1.3.1 The problem of unfamiliar face recognition

Recognition of unfamiliar faces from different pictures is surprisingly error-prone. In fact, it can be quite difficult to establish that two images show the same unfamiliar person. For example, Bruce and colleagues showed that participants make approximately 30% errors when a target face has to be recognised from a different image in a simultaneously presented array of 10 faces (Bruce et al., 1999; see also Megreya & Burton, 2006). As expected, performance was best, but still surprisingly low, when both images of the target were similar with respect to viewpoint and expression but dropped when a change in expression and, in particular, viewpoint was introduced. Error rates remain high in pairwise matching tasks where participants have to decide whether two simultaneously presented images are two different images of the same person or of two different people (Burton, White, & McNeill, 2010; Megreya & Burton, 2006, 2007). Moreover, performance did not improve when a photograph had to be matched to a live target rather than another photograph (Megreya & Burton, 2008). Importantly, these findings held in a series of experiments where mismatch trials occurred only occasionally, which arguably more closely resembles the very infrequently occurring mismatches in real life scenarios (Bindemann, Avetisyan, & Blackwell, 2010). The high error rates observed in unfamiliar face matching are particularly striking considering that these poor levels of performance arise when decisions have to be made for *simultaneously* presented images. In addition, the images collected for the experiments discussed above were almost always taken on the same day, and there is evidence that unfamiliar face matching performance is further reduced when images were taken approximately 1.5 years apart (Megreya, Sandford, & Burton, 2013).

While most of these studies use designs that more or less mirror identification that is required in applied settings (e.g., line-ups, passport control), similarly high error rates have also been observed in studies conducted in real environments. For instance, Kemp, Towell, and Pike (1997) found that cashiers who worked in a supermarket made a substantial amount of errors (around 30%) when having to verify whether photo-ID cards presented by the shopper indeed show this person. Even more strikingly, people who are trained to perform identity checks, such as police or passport officers, often do not perform better than student samples (Burton, Wilson, Cowan, & Bruce, 1999; White, Kemp, Jenkins, Matheson, & Burton, 2014; Wirth & Carbon, 2017; but see Towler, White, & Kemp, 2017; White, Phillips, Hahn, Hill, & O'Toole, 2015). As a result of such findings, the usefulness of photo-ID has been questioned (Bindemann & Sandford, 2011; Ritchie et al., 2015; White, Burton, Jenkins, & Kemp, 2014).

Figure 1.1 Exemplary ambient images. All images show the same person. Images are reprinted with full permission of the depicted person.

Difficulties with unfamiliar faces are also clearly apparent in so-called sorting tasks in which participants are presented with multiple “ambient” images (Jenkins, White, Van Montfort, & Burton, 2011). These images show a given face across a wide range of unsystematic variability (usually termed “within-person variability”), e.g., with respect to expression, viewing angle, hairstyle, and age (see Figure 1.1). Jenkins et al. (2011) presented participants with 20 images of each of two Dutch celebrities that were unknown to their UK participants. The task was to sort these images into as many piles as they perceived identities in the set. Quite surprisingly, participants substantially overestimated the number of identities in the set and perceived 7.5 different identities on average. In fact, not a single participant arrived at the correct solution (see also Andrews, Jenkins, Cursiter, & Burton, 2015). Interestingly, participants rarely sort images of the two different identities into the same pile, suggesting that participants can easily “tell faces apart” (Andrews et al., 2015). However, they had profound difficulties “telling faces together”, i.e., to establish that different images actually show the same person (Andrews et al., 2015; Jenkins et al., 2011). These studies clearly highlight the difficulty of unfamiliar face recognition and the particular challenge to recognise a given face across a substantial amount of variation.

1.3.2 Differences between unfamiliar and familiar face recognition

In contrast, these matching and sorting tasks are typically trivially easy when participants are familiar with the faces. For instance, participants are significantly better at matching familiar than unfamiliar faces (e.g., Noyes & Jenkins, 2017; Ritchie et al., 2015; White, Burton, et al., 2014). In addition, Dutch participants familiar with the identities in Jenkins et al. (2011) performed perfectly (see also Zhou & Mondloch, 2016).

These profound differences in performance between unfamiliar and familiar faces most likely reflect differences in how they are represented. Familiar face recognition is thought to rely on stored memory representations that gradually develop over time. These structural codes, termed face recognition units (FRUs; Bruce & Young, 1986), become increasingly abstract, i.e., independent of particular viewing conditions, the more we become familiar with a face and therefore allow for recognition across a substantial range of variation (Burton et al., 1999; Etchells, Brooks, & Johnston, 2017). For any unfamiliar face, however, such representations are not available. Instead, unfamiliar face recognition is largely based on pictorial codes that are closely tied to the original encounter with a given face (e.g., Hancock, Bruce, & Burton, 2000). As a consequence, small variations between images of an unfamiliar person, brought about by changes in e.g., pose, lighting, expression, or hairstyle (for a review, see Johnston & Edmonds, 2009), are typically found to impair performance (e.g., Bruce et al., 1999; Longmore, Liu, & Young, 2008; Megreya & Burton, 2006).

1.3.3 How do unfamiliar faces become familiar?

Initial research into understanding how faces become familiar relied on the concept of averages. The idea of this approach was that averaging together multiple images of a given face cancels out image-specific variation (which accordingly treated as “noise” by this approach) but preserves aspects that are stable across images (Burton, Jenkins, Hancock, & White, 2005). Support comes from computational findings showing that averages are often better recognised than individual images (Jenkins & Burton, 2008; but see Ritchie, Kramer, & Burton, 2018 for better recognition of familiar faces from ‘good likeness’ pictures than from averages in human participants). In addition, individual images are matched more accurately to an average than to another individual image, a finding reported for both unfamiliar and familiar faces (White, Burton, et al., 2014). However, these authors observed that, compared to matching an individual image to an average, higher matching performance was obtained when an individual image had to be matched to an array consisting of five individual images of a given person. This suggests that information about the variability of a given face may also be important and that averages can only provide very limited information with regard to within-person variability (see e.g., Burton, Kramer, Ritchie, & Jenkins, 2016; Jenkins & Burton, 2011).

More recently, researchers have begun to incorporate rather than to eliminate within-person variability which has been argued to be fundamental to familiar face recognition and face learning (Burton, 2013; for computational approaches, see Burton et al., 2016; Kramer, Young, & Burton, 2018). Andrews and colleagues showed that exposing participants to within-person variability leads to the acquisition of image-independent representations for these faces in memory (Andrews, Burton, Schweinberger, & Wiese, 2017; Andrews et al., 2015). In these studies, participants again had to sort ambient images according to identity. However, this time participants were informed that only two identities were present in the card set, which improved performance substantially. More importantly, this variant of the sorting task seems to lead to incidental learning of the faces presented during sorting, because it encourages participants to learn that the same person can look very different in different images. Specifically, in a subsequent matching task, previously unseen images of the identities seen during the sorting task were matched more accurately than images of unfamiliar identities, suggesting that representations have been formed in the course of sorting that can facilitate performance with these faces on a subsequent task, independent of the pictures used during incidental learning (Andrews et al., 2015). In addition, learning identities from a highly variable set has been shown to facilitate face learning to a greater extent than when identities are learnt from less variable sets (Liu, Chen, & Ward, 2015; Murphy, Ipser, Gaigg, & Cook, 2015; Ritchie & Burton, 2017), suggesting that exposure to variability may be a key factor in learning faces (see also Kramer, Jenkins, Young, & Burton, 2017).

1.3.4 Differences between own- and other-race faces

As detailed in the previous paragraphs, variability between images of an unfamiliar face can have a detrimental effect on performance. As a result, different pictures of unfamiliar faces are matched less accurately and recognised less well than pictures of familiar faces. More recently, it has been shown that these difficulties are even more pronounced for unfamiliar other-race faces. First, other-race faces are matched less accurately than own-race faces (Kokje, Bindemann, & Megreya, 2018; Megreya & Bindemann, 2009; Megreya et al., 2011). Second, when participants are required to sort multiple ambient images of two faces into as many piles as they perceive identities, they perceive even more other- than own-race identities (Laurence et al., 2016; Yan et al., 2016; Zhou & Mondloch, 2016). These studies clearly show that within-person variability has an even stronger negative effect on the perception of identity in other-race faces.

More recently, researchers have started to investigate own- and other-race face learning. Initial evidence for image-independent other-race face learning was provided by Matthews and Mondloch (2018) who showed that participants were able to learn other-race identities after receiving extensive training that included multiple images per identity and different tasks. However, given that participants were only trained with other-race identities, this study cannot offer any insights into whether own- and other-race faces are learnt equally well.

Proietti, Laurence, Matthews, and Mondloch (2018) showed that shifting participants' attention to individuating information in own- and other-race faces during learning did not attenuate the ORB. In this study, faces were learnt either in a passive viewing task similar to typical old/new recognition experiments or in a pairwise matching task. Both learning tasks gave rise to an ORB and a trend was observed for the ORB to be more pronounced when faces were learnt in a matching relative to a passive viewing task, suggesting that it is more difficult to extract identity-related information from other- compared to own-race faces. Similarly, own- and other-race faces have been observed to equally benefit from multi-image training (Cavazos, Noyes, & O'Toole, 2018). Here, although an ORB was still present, presenting multiple images during learning promoted establishing a representation that can facilitate subsequent recognition of novel exemplars. However, in both studies, each identity was represented by a very limited number of images (two in Proietti et al., 2018; four in Cavazos et al., 2018). In addition, Proietti et al. (2018) used identical images at learning and test.

The first evidence that other-race facial identities are harder to learn than own-race faces was provided by Hayward et al. (2017). In this study, both Caucasian and Asian participants learned face-name associations for own- and other-race identities to a given criterion and afterwards had to name the faces from previously unseen images. Participants took longer to learn other- compared to own-race identities, and also recognised other-race faces less well from novel instances, suggesting that it is more difficult to learn other-race faces from multiple, varying images. A similar benefit for own-race face learning was also demonstrated by Zhou and colleagues (Zhou et al., 2018; see also Baker, Laurence, & Mondloch, 2017). Here, Caucasian participants learned Caucasian and East Asian faces from a single image, a low-variability or a high-variability video, and afterwards had to recognise these faces from new instances. The authors observed a general benefit of variability during learning which promoted subsequent recognition. However, a higher degree of variability was required to learn other- than own-race faces, suggesting higher efficiency to use variability in own- relative to other-race identities.

From a theoretical perspective, increased difficulties with perceiving image-independent identity of other-race faces are typically considered to reflect reduced perceptual expertise with the other-race category. In other words, reduced perceptual expertise with other-race faces not only impairs recognition of these faces but also our ability to perceive identity across different images of a given face. In line with this suggestion, Short and Wagler (2017) did not observe differences in performance in a sorting task when the faces belonged to social in- or out-groups but did not differ with respect to expertise. Similarly, the findings that other-race identities are less well learnt are also in line with perceptual expertise accounts. Learning paradigms arguably encourage individuation of both own- and other-race identities as they emphasise that the identity of *all* faces is important and emphasise the integration of different images into an abstract representation independent of stimulus ethnicity. In addition, it has been argued that such learning paradigms more closely resemble the challenge of other-race faces in real life where a given person may look quite different across different encounters (see e.g., Hayward et al., 2017). Thus, this research may represent an important step towards understanding how own- and other-race identities are learnt in real life. However, as this area of research has only recently developed, more research is clearly needed to gain a deeper understanding of how own- and other-race faces are learnt from variation.

1.4 Neural correlates of the ORB

Face processing is thought to consist of a number of successive processing steps. For example, the influential model by Bruce and Young (1986) conceptualised face recognition as a process that involves several distinct functional processes, such structural encoding, accessing perceptual face representations, and accessing person-related semantic information and names (see also Schweinberger & Neumann, 2016). While the ORB in memory is a purely behavioural measure that can only inform about the outcome of these processes, event-related brain potentials (ERPs) can offer a detailed and fine-grained analysis of the neuro-cognitive processes underlying face processing. ERPs reflect transient voltage changes in the human electroencephalogram (EEG) that are time-locked to a particular event, e.g., the presentation of a visual stimulus. ERPs reflect postsynaptic potentials, mainly from cortical pyramidal cells, which last about tens to hundreds of milliseconds. When postsynaptic potentials occur simultaneously in thousands of neighbouring neurons with a similar orientation, they sum together and are conducted intracranially and through the skull. This results in a voltage change that can be recorded instantaneously with electrodes placed on the scalp (Luck, 2014). The resulting ERPs consist of positive and negative deflections (so-called components) which are associated with distinct stages of stimulus processing. Thus, ERPs are ideally suited to provide insights into the distinct processing steps between the presentation of a stimulus and the participant’s response.

1.4.1 N170

The first face-sensitive ERP component is the N170, a negative deflection peaking approximately 170 ms after stimulus onset at occipito-temporal electrode sites (see Figure 1.2). N170 is generally found to be more negative for faces than for any other class of objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996). Moreover, N170 is typically unaffected by familiarity, i.e., its amplitude is similar for familiar and unfamiliar faces (Bentin & Deouell, 2000; Eimer, 2000a; Schweinberger, Pfütze, & Sommer, 1995; Zimmermann & Eimer, 2013, 2014). These findings have led to suggestions that N170 reflects processes that precede the identification of a face at the individual level. In particular, N170 has been interpreted as a marker of structural encoding of faces or the detection of a face-like pattern (Eimer, 2000b; Eimer, 2011). At some variance with the idea that N170 is insensitive to familiarity, N170 has sometimes been found to be reduced for immediate face repetitions (e.g., Caharel, d'Arripe, Ramon, Jacques, & Rossion, 2009). However, these identity adaptation effects within the N170 time range are comparatively small and only observed for relatively minor changes between adapter and test stimulus (Caharel, Collet, & Rossion, 2015; Herzmann, Schweinberger, Sommer, & Jentzsch, 2004; Jacques & Rossion, 2007). It has therefore been suggested that these somewhat transient adaptation effects are mediated by pictorial rather than structural codes (for a more detailed discussion of adaptation effects within the N170 time range, see Schweinberger & Neumann, 2016).

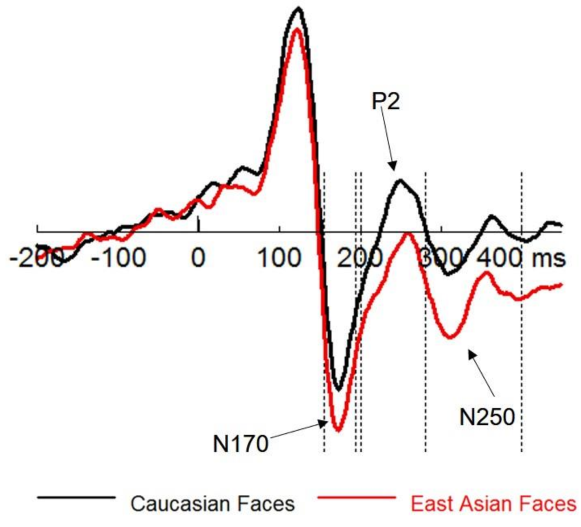

Figure 1.2 Illustration of perceptual ERP components. Data show N170, P2, and N250 ERP components for Caucasian and East Asian faces in Caucasian participants recorded during the learning phase of an old/new recognition memory experiment. Dotted lines denote exemplary time ranges selected for calculation of mean amplitudes for N170, P2, and N250 components.

N170 is often more negative for other- when compared to own-race faces (e.g., Balas & Nelson, 2010; Caharel et al., 2011; Cassidy, Boutsen, Humphreys, & Quinn, 2014; Gajewski, Schlegel, & Stoerig, 2008; Herrmann et al., 2007; Herzmann, Minor, & Curran, 2018; Stahl, Wiese, & Schweinberger, 2010; Wiese, 2012; Wiese et al., 2014; Wiese & Schweinberger, 2018), which has been interpreted to reflect more effortful structural processing of other-race faces. However, some studies did not find ethnicity effects within the N170 time range (e.g., Caldara, Rossion, Bovet, & Hauert, 2004; Herzmann et al., 2011; Ito et al., 2004; Wiese, Stahl, & Schweinberger, 2009). These differential findings may, at least to a certain extent, reflect differential task demands. Specifically, N170 ethnicity effects are typically observed when identity information is task-relevant, but absent when the face stimuli are not task-relevant (Senholzi & Ito, 2013; Wiese, 2013).

1.4.2 P2

Subsequent to N170, a positive deflection, the P2 component (Figure 1.2), is observed that peaks roughly 200 ms after stimulus onset at occipito-temporal sites. P2 is thought to reflect the perceived typicality of a given face relative to a prototype. For instance, P2 is more positive for veridical as compared to spatially caricatured face stimuli (Kaufmann & Schweinberger, 2012; Schulz, Kaufmann, Kurt, & Schweinberger, 2012; Wuttke & Schweinberger, 2019).

P2 is also more positive for own- relative to other-race faces (Stahl et al., 2010; Wiese, 2012; Wiese et al., 2014; Wiese & Schweinberger, 2018), although this effect was found to be attenuated in participants with a high amount of other-race contact (Stahl, Wiese, & Schweinberger, 2008). In addition, while participants attending to ethnic category information during learning showed a P2 ethnicity effect, a comparable effect was absent in participants instructed to focus on individuating information in own- and other-race faces during learning (Stahl et al., 2010). These findings suggest that P2 is sensitive to our long-term experience with faces of given category as well as current task demands.

1.4.3 N250

The first ERP component consistently observed to be sensitive to individual face identity and face recognition is the N250 (Figure 1.2), a negative deflection over occipito-temporal electrode sites starting at approximately 250 ms after stimulus onset. Compared to unfamiliar faces, more negative N250 components are elicited by famous (Andrews et al., 2017; Gosling & Eimer, 2011) and personally familiar faces (Wiese et al., in press) as well as the participant’s own face (Tanaka, Curran, Porterfield, & Collins, 2006). More negative N250 components have also been observed for immediate face repetitions compared to when a face is preceded by a different face, the so-called N250r (r for repetition; Begleiter, Porjesz, & Wang, 1995; Schweinberger, Huddy, & Burton, 2004; Schweinberger et al., 1995). For familiar faces, this N250r is also observed, albeit reduced in amplitude, for repetitions across different images (e.g., Bindemann, Burton, Leuthold, & Schweinberger, 2008; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002). These findings suggest that the N250/N250r reflects access to perceptual face representations. More negative N250 amplitudes have also been reported for other- relative to own-race faces (Herzmann et al., 2011; Herzmann et al., 2018; Stahl et al., 2010; Wiese et al., 2014; Wiese & Schweinberger, 2018), which has been interpreted to reflect more effortful processing of other-race faces when these have to be processed at an individual level (Herzmann, 2016).

The N250 component is also associated with face learning and more negative N250 components have been found in response to recently learnt when compared to unfamiliar faces (e.g., Tanaka et al., 2006). Whereas Tanaka et al. (2006) used identical images at learning and test, N250 learning effects have also been obtained across different images of the respective faces (Kaufmann, Schweinberger, & Burton, 2009). This suggests that training may have encouraged the development of an FRU-like face representation that is, to some extent, image-independent and can accommodate previously unseen instances of recently learnt faces. N250 learning effects reported by Kaufmann et al. (2009) were found to peak slightly later and were observed at longer lags compared to the N250/N250r effects described above. This may suggest that representations for newly learnt faces require more time to be accessed than those for highly familiar or very recently presented faces.

Tanaka and Pierce (2009) observed increased N250 amplitudes after Caucasian participants received extensive training to individuate African American or Hispanic faces. In contrast, a comparable effect was absent when participants had to categorise these faces according to race. This suggests that individuation training can overcome the recognition deficit for other-race faces and elicit neural responses associated with familiar face recognition (Tanaka & Pierce, 2009). However, this study again used identical images during learning and test. Thus, it remains possible that learning effects observed in this study reflect the learning of a particular image set rather than actual face learning that is independent of a specific image set.

The first ERP study to investigate face learning from highly variable images was conducted by Andrews et al. (2017). Participants first completed a sorting task where multiple, ambient images of two identities had to be sorted into separate identity piles. Subsequently, these images elicited more negative N250 amplitudes than faces of previously unseen identities. More importantly, highly similar N250 learning effects were also observed for previously unseen images of the learnt identities, which were indistinguishable from those found for the image set presented during sorting. This suggests that representations for recently learnt faces are sufficiently robust or image-independent to incorporate new images. While this study provides a neural correlate for image-independent face learning, it remains to be addressed whether own- and other-race faces are learnt similarly efficiently from highly variable images.

1.4.4 Encoding-related ERPs

While the ERP components described in the previous sections reflect perceptual face processing or the establishment of perceptual face representations in the course of face learning, a somewhat different approach is to examine the neural processes associated with successful versus unsuccessful learning. Here, brain activity during stimulus encoding is compared for items that are subsequently remembered and forgotten (for a more detailed illustration, see Figure 1.3).

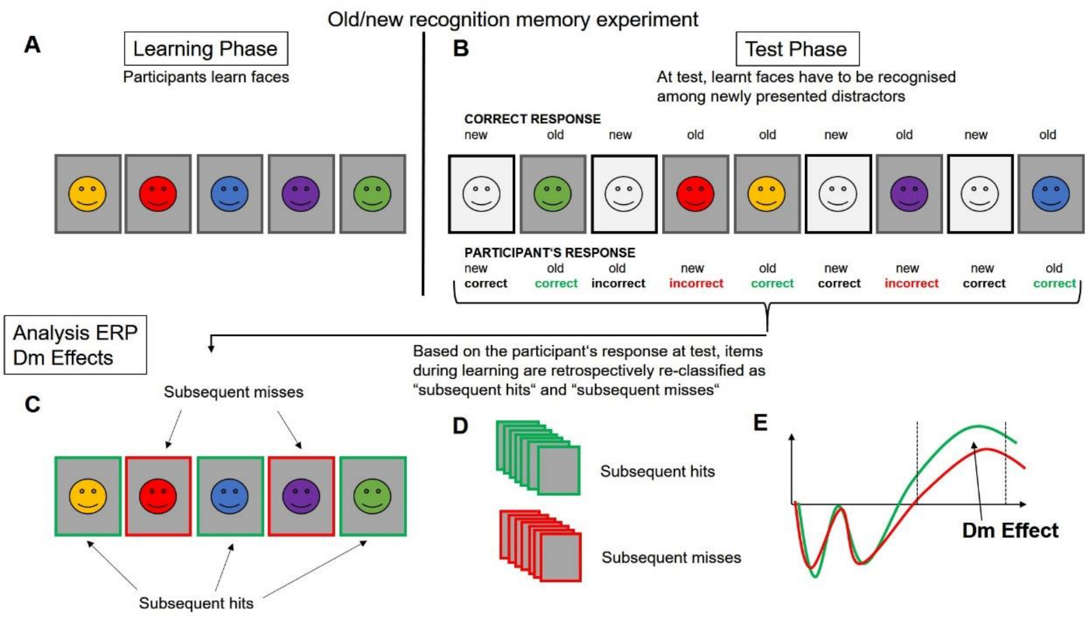

Figure 1.3 Illustration of how ERP Dm effects are analysed. During an old/new recognition experiment, participants learn faces (A) and subsequently, at test (B), have to recognise them among new items. Based on each individual participant's response, items presented during the learning phase are retrospectively categorised as "subsequent hits" and "subsequent misses" (C). Afterwards, items are averaged according to experimental conditions for each participant and across participants (D). Exemplary grand averages (E) for subsequent hits and subsequent misses. Starting approx. 300 ms after stimulus onset, more positive amplitudes are observed for subsequent hits compared to misses over centro-parietal sites.

This so-called ERP Dm effect (<u>d</u>ifference due to subsequent <u>m</u>emory) was originally reported for words (Paller, Kutas, & Mayes, 1987), but has also been found for faces (Sommer, Heinz, Leuthold, Matt, & Schweinberger, 1995; Sommer, Schweinberger, & Matt, 1991). Items later remembered typically elicit a widespread positivity relative to later forgotten items, which is maximal over centro-parietal scalp sites from approximately 300 ms after stimulus onset (Paller et al., 1987). Only a handful of studies so far have investigated ERP Dm effects for own- and other-race faces (Herzmann, Minor, & Adkins, 2017; Herzmann et al., 2011, 2018; Lucas, Chiao, & Paller, 2011). While these experiments and their findings will be discussed in more detail in Chapter 3, they suggest that own-race faces are processed more elaborately and efficiently compared to other-race faces. Importantly, ERP Dm effects may be a useful tool to investigate the effect of manipulations that aim at eliciting more detailed encoding of other-race faces (i.e., individuating instructions; Hugenberg et al., 2007).

1.5 The present thesis

The aim of this thesis is to investigate the role of perceptual expertise and socio-cognitive factors for the ORB with different paradigms and measures. The first part of this thesis (Chapters 2 and 3) examines the extent to which motivation to individuate can modulate the ORB. These experiments are aimed at testing predictions derived from socio-cognitive models of the ORB. In the second part of this thesis (Chapters 4 and 5), it is investigated whether own- and other-race facial identities are learnt equally well from multiple, highly variable images. As discussed above, these learning paradigms encourage individuation and are arguably not strongly affected by differential motivational or attentional factors.

As described in more detail above, behavioural measures inform about the outcome of various cognitive processes. At the same time, ERPs can offer a more fine-grained analysis of the distinct processing stages between the presentation of a stimulus and the participant’s response, rendering them a promising tool to provide insights into the neural processing of own- and other-race faces. Each part of this thesis starts off with a set of behavioural experiments (Chapters 2 and 4) aimed at closely investigating the differences between own- and other-race faces with a given paradigm and, at least to some extent, at replicating these findings to increase confidence in the results. In a further step, ERP experiments investigate the neural correlates underlying these effects (Chapters 3 and 5).

The first two chapters examine whether increasing motivation to individuate can attenuate the ORB. In Chapter 2, five behavioural experiments are reported that investigate the extent to which intentional and motivational aspects can modulate the ORB as well as potentially related memory biases (i.e., own-group bias, own-gender bias) that arguably cannot be explained in terms of differential perceptual expertise. To this end, directed forgetting (Bjork, 1970), a well-established paradigm in the memory literature, was applied to various in- and out-group faces. These experiments reveal that a modulation of face memory by the intention to remember or forget is possible, but restricted to face categories for which we have acquired a substantial amount of expertise.

In a further step, Chapter 3 investigates whether explicitly informing participants about the ORB and instructing them to pay particular attention to other-race faces during learning can eliminate the effect (Hugenberg et al., 2007). Here, a particular interest was whether these individuating instructions modulate the ERP Dm effect, where neural activity during learning is compared for items subsequently remembered and items subsequently forgotten. The results show that individuating instructions attenuated the ORB in recognition memory and also resulted in significantly larger ERP Dm effects for other-race faces. These findings are generally in line with socio-cognitive accounts, as they suggest that participants are able to individuate other-race faces when instructed to do so, which in turn reduces the ORB. At the same time, ERP findings suggest that successful learning of other-race faces may require additional effort and thus, factors other than reduced motivation to individuate other-race faces likely contribute to the ORB in this experiment.

Chapters 4 and 5 investigate whether own- and other-race facial identities can be learnt equally well from highly variable photographs. Participants initially sorted multiple images of two own- and two other-race identities into separate identity clusters and subsequently were required to recognise these identities from previously unseen images. In Chapter 4, across two experiments, Caucasian participants show a clear own-race advantage in face learning while East Asian participants with substantial other-race contact show comparable identity learning for own- and other-race faces.

A further experiment (Chapter 5) investigates the neural basis of this effect. ERP results reveal that, compared to other-race faces, learnt own-race identities were processed more efficiently at a perceptual level, as indicated by more negative N170 components and less positive P2 components for learnt compared to previously unseen faces. The N250, a component consistently associated with face learning, was more negative for learnt relative to novel faces irrespective of ethnicity, but also more negative for other-race faces overall, which may suggest more effortful processing of other-race faces.

These experiments suggest that the ORB is primarily driven by differential perceptual expertise, but that socio-cognitive and motivational factors can, under certain circumstances, modulate the effect. For participants without extensive experience with other-race faces, the ORB mainly results from their reduced expertise with the other-race face category and a modulation of the effect by motivational factors is only possible to some extent. However, when participants have acquired substantial expertise with the other-race face category, increased motivation to individuate can eliminate the ORB.

2 Directed forgetting of own- and other-race faces

People are better at remembering faces of their own relative to another ethnic group. This so-called own-race bias (ORB) has been explained in terms of differential perceptual expertise for own- and other-race faces or, alternatively, as resulting from socio-cognitive factors. To directly test predictions derived from these accounts, we examined item-method directed forgetting (DF), a paradigm sensitive to an intentional modulation of memory, for faces belonging to different ethnic and social groups. In a series of five experiments, participants during learning received cues following each face to either remember or forget the item, but at test were required to recognise all items irrespective of instruction. In Experiments 1 and 5, Caucasian participants showed DF for own-race faces only while, in Experiment 2, East Asian participants with considerable expertise for Caucasian faces demonstrated DF for own- and other-race faces. Experiments 3 and 4 found clear DF for social in- and out-group faces. Contrary to recent socio-cognitive models of the ORB, our results suggest that a modulation of face memory by motivational processes is limited to faces with which we have acquired perceptual expertise. Thus, motivation alone is not sufficient to modulate memory for other-race faces and cannot fully explain the ORB.

2.1 Introduction

Humans demonstrate remarkable performance recognising faces every single day. However, this high level of accuracy does not apply equally to all classes of faces. Of particular interest for the present study, people are usually better at remembering faces of their own relative to a different ethnic group (for a review, see Meissner & Brigham, 2001). This so-called own-race bias (ORB; or other-race effect) is a robust and well-established finding. Failing to correctly recognise an individual can not only negatively impact social interactions, but becomes even more critical in legal contexts where erroneous eyewitness testimonies can lead to wrongful convictions. Given the ORB, such misidentifications appear more likely for other- relative to own-race faces. However, while these applied problems stress the relevance of research on the ORB, the exact mechanisms underlying the phenomenon are still subject to considerable debate.

A first class of theoretical explanations for the ORB focuses on perceptual expertise. These accounts assume that face recognition is optimised for those faces we most regularly encounter, which happen to be own-race faces for most people. On the one hand, reduced contact and the resulting lack of experience with other-race faces has been suggested to result in less efficient perceptual, e.g., configural or holistic processing (Hayward, Crookes, & Rhodes, 2013; Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2004). On the other hand, representational accounts propose that the multidimensional face-space (MDFS, Valentine, 1991), a psychological space in which individual faces are coded along multiple dimensions, develops through perceptual learning over the lifespan. The dimensions are therefore fine-tuned to optimally distinguish between those faces we encounter most often (i.e., own-race faces), but are not optimal to represent and distinguish between other-race faces (Valentine & Endo, 1992; Valentine, Lewis, & Hills, 2016). Both less efficient perceptual processing and less accurate representations should in turn result in less accurate memory for other-race faces.

Alternatively, socio-cognitive accounts propose that the ORB is strongly affected by motivational factors (Young, Bernstein, & Hugenberg, 2010; Young, Hugenberg, Bernstein, & Sacco, 2012). As one example from this family of theoretical accounts, the Categorization-Individuation Model (CIM, Hugenberg, Young, Bernstein, & Sacco, 2010) suggests three distinct factors to underlie the ORB. First, a fast and automatic categorisation of a given face as belonging to the perceiver's in- or out-group is assumed. This in- versus out-group categorisation is not specific to ethnicity, but can be based on various stimulus characteristics (e.g., age, gender, or even information derived from the context in which the face is presented, such as university affiliation; for a discussion of in- vs. out-group categories, see Hugenberg, Wilson, See, & Young, 2013). While out-group faces are per default not processed beyond this initial detection of category-diagnostic features, in-group faces are individualised, leading to superior memory for this latter category. Second, however, perceiver motives can serve to direct attention to either category- or identity-diagnostic characteristics of a face. Consequently, people are able to individuate out-group (e.g., other-race) faces if sufficiently motivated (Hugenberg, Miller, & Claypool, 2007). Finally, CIM acknowledges the role of prior experience with a given class of faces, such as faces of certain ethnic groups, when discriminating between them. However, expertise is only fully employed for those faces which perceivers are motivated to individuate. To summarise, while expertise accounts assume that difficulties with other-race face recognition stem from a lifetime lack of contact and consequent *inability* to individuate these faces, socio-cognitive accounts posit that perceivers are not *motivated* to individuate other-race faces, but given sufficient motivation would be well able to do so.

In support of the latter suggestion, the ORB has been reported to be absent for faces depicting high-power (Shriver & Hugenberg, 2010) and angry individuals (Ackerman et al., 2006). In addition, individuating instructions can eliminate the ORB (Hugenberg et al., 2007; Rhodes, Locke, Ewing, & Evangelista, 2009; Young et al., 2010). In these studies, participants are informed about the ORB prior to taking part in the experiment. Additionally, they are asked to pay more attention to other-race faces to overcome the ORB and instructed to focus on individuating features in other-race faces. Interestingly, such effects of individuating instructions seem to depend on expertise. Accordingly, two recent studies (Pica, Warren, Ross, & Kehn, 2015; Young & Hugenberg, 2012) reported stronger reduction of the ORB following individuation instructions in participants with high levels of interracial contact. These results can be explained in terms of the CIM (Hugenberg et al., 2010) if one assumes that participants with more other-race contact are also more motivated to individuate other-race faces (and therefore enhanced expertise can become effective). However, it has to be noted that some studies have failed to replicate instruction effects (Tullis, Benjamin, & Liu, 2014; Wan, Crookes, Reynolds, Irons, & McKone, 2015). Similarly, a recent paper by Crookes and Rhodes (2017) found that increased motivation and effort to individuate other-race faces does not necessarily improve other-race face recognition.

Further support for a socio-motivational contribution to the ORB comes from studies in which the ORB is modulated by a second purely social category which is orthogonal to race (e.g., university affiliation). For instance, Shriver, Young, Hugenberg, Bernstein, and Lanter (2008) reported that the ORB is reduced for faces of fellow university students. Moreover, grouping own- and other-race faces according to this social category during learning has been observed to completely eliminate the ORB (Hehman, Mania, & Gaertner, 2010). However, this latter finding was not replicated in a more recent study (Kloth, Shields, & Rhodes, 2014) which found an ORB indendent of whether the faces were grouped according to race or university categories. Taken together, while some studies report socio-motivational factors to strongly modulate the ORB, others have found this modulation to depend on expertise (whereas the CIM suggests that expertise effects depend on motivation) or did not find the respective effects.

In the present series of experiments, we aimed at further testing the role of socio-cognitive and motivational factors to the ORB. To this end, we employed directed forgetting (DF, Bjork, 1970; Woodward & Bjork, 1971), a well-established experimental paradigm sensitive to motivational and intentional aspects of memory, to the study of the ORB. As we hope will become clear in the following paragraphs, DF provides an excellent tool for this endeavour.

While previous research has used two variants of the DF procedure, item- and list-method DF (Anderson, 2005; Basden & Basden, 1996; MacLeod, 1999), we will focus on the former paradigm for the present study. In item-method DF, participants receive a cue following each item presented during the learning phase, instructing them to either remember or forget the item. In a subsequent test phase, memory for both to-be-remembered (TBR) and, surprisingly, to-be-forgotten (TBF) items is tested. This typically results in a so-called DF effect, reflecting superior memory for TBR as opposed to TBF items. Item-method DF is thought to result from distinct processes that are intiated upon presentation of the TBR or TBF cues. While a TBR cue results in selective rehearsal and in-depth processing of an item, a TBF cue stops rehearsal and actively inhibits a previously presented item (Anderson & Hanslmayr, 2014; Basden, Basden, & Gargano, 1993; Fawcett & Taylor, 2008; Nowicka, Jednorog, Wypych, & Marchewka, 2009; Paz-Caballero, Menor, & Jimenez, 2004).

Traditionally, experiments using the DF paradigm have employed verbal material. More recently, however, the DF procedure has also been applied to other types of stimuli, such as line drawings (Lehman, McKinley-Pace, Leonard, Thompson, & Johns, 2001) and pictures (e.g., Hauswald & Kissler, 2008; Hauswald, Schulz, Iordanov, & Kissler, 2011). These studies usually replicate the DF effect obtained with verbal material, although it is sometimes smaller in size (Basden & Basden, 1996; Hauswald & Kissler, 2008; Paller, Bozic, Ranganath, Grabowecky, & Yamada, 1999; Quinlan, Taylor, & Fawcett, 2010). So far, only very few studies have investigated DF using faces. A DF effect is typically reported in these studies (Fitzgerald, Price, & Oriet, 2013; Goernert, Corenblum, & Otani, 2011; Metzger, 2011; Paller et al., 1999; but see Reber et al., 2002), suggesting that memory for faces is to some extent susceptible to intentional forgetting.

At a first glance, the suggestion to use DF to investigate socio-cognitive and expertise-related mechanisms of the ORB might appear counterintuitive. Both categorising faces into social in- versus out-groups and expertise-based perceptual mechanisms are supposed to be immediately engaged upon presentation of the face stimulus whereas the DF instructions are not delivered until *after the offset* of the stimulus. Closer consideration, however, might render this paradigm interesting for the present research question. More specifically, at stimulus onset participants do not know whether the face will be followed by a TBR or TBF cue, and this applies equally to own- and other-race faces. Accordingly, participants may *initially* be motivated to process all faces as they wait for the instruction to either remember or forget the face. Upon presentation of the memory cues, the instruction should then modulate the extent to which faces are further processed in memory. As described above, a TBR cue should elicit further elaborative processing and rehearsal, whereas a TBF cue should result in dropping the respective items from rehearsal and/or inhibiting them (e.g., Basden et al., 1993). While, as discussed in the previous paragraphs, faces have generally been shown to be susceptible to DF, here we were particularly interested in the extent to which DF can modulate memory for own- and other-race faces, respectively. As will be explained in more detail below, different predictions for DF of own- and other-race faces can be derived from expertise- and socio-cognitive accounts.

In the following, we report five experiments which systematically investigated the influence of intentional forgetting on memory for faces of different categories. In particular, we examined DF for own- and other-race faces in Caucasian participants (Experiments 1 and 5) and an East Asian sample living in the UK (Experiment 2). In addition, DF was applied to purely social in- and out-group faces (Experiment 3) as well as own- and other-gender faces (Experiment 4).

2.2 Experiment 1

Experiment 1 investigated DF for own- and other-race faces to test predictions derived from expertise-related and socio-cognitive explanations of the ORB. First, expertise accounts propose that, due to a lack of experience, other-race faces are not optimally processed and/or represented, and therefore predict differential DF effects for own- and other-race faces. More specifically, for own-race faces, a detailed and accurate representation for each individual stimulus is created, which is distinct from (most) other representations. A cue to remember should encourage the transfer of this representation into long-term memory, while a cue to forget should prevent further processing and/or inhibit the representation. Accordingly, we expected better memory for TBR compared to TBF items. For any individual other-race face, however, the representation will be substantially less precise, and will be similar to other representations of other-race faces. Therefore, while an instruction to remember the face will transfer the representation into memory, it will be similar to other representations, resulting in enhanced confusion among them at test. Importantly, while an instruction to forget will inhibit this specific representation, other highly similar representations will exist in memory. Paradoxically, even if participants successfully inhibit an other-race face during learning, when presented as a test item, this “forgotten” face will look similar to other stimuli that were successfully encoded, and will therefore be more likely mixed up with a different representation and then “falsely remembered”. Accordingly, no or only a small DF effect for other-race faces would be expected.

Alternatively, socio-cognitive accounts suggest that the ORB results from a tendency to individuate own-race faces but to process only category-diagnostic information in other-race faces. The CIM (Hugenberg et al., 2010) additionally posits that perceiver motives serve to direct attention to category- or identity-diagnostic information in both own- and other-race faces. As discussed in more detail above, participants in the DF paradigm should initially be motivated to individuate all faces as they wait for the instruction to either remember or forget a face. Thus, in line with the suggestion that people *are able* to individuate all faces if they are sufficiently motivated, we would expect a clear DF effect for both own- *and* other-race faces. If participants were able and motivated to individuate both own- and other-race faces, the resulting representations should be similarly accurate and detailed. TBR cues should then elicit transfer of both own- and other-race items into long-term memory, while a TBF cue should stop further rehearsal and inhibit both own- and other-race faces. Accordingly, we would expect better memory for TBR compared to TBF faces for both stimulus categories.

2.2.1 Method

Participants

36 undergraduate and postgraduate students (18 – 32 years, $M = 20.22$, $SD = 3.01$, 32 female) gave written informed consent to take part in the study. All had a Caucasian ethnic background and normal or corrected-to-normal vision. Participants received course credit or £5 for partaking. The study was approved by the local Ethics Committee.

Stimuli and Apparatus

A set of 128 colour photographs of unfamiliar faces was used as stimuli (for origin of images and more detailed information regarding ratings of ethnic typicality, see Wiese, Kaufmann, & Schweinberger, 2014). The selected photographs displayed portraits with full frontal views and neutral expressions. Half of the photographs depicted Caucasian faces, the other half were of East Asian faces. Half of the faces within the respective ethnic categories were female. Using Adobe Photoshop (CS4 Extended, 11.0.2), faces were cut out to remove any extraneous information (e.g., clothing, background) and pasted to a uniform black background. Stimuli were framed within an area of 300 x 400 pixels (10.9 x 15.6 cm) resulting in a visual angle of 6.2° x 8.9° at a viewing distance of approximately 100 cm. All stimuli were presented on dark grey background in the centre of a computer monitor with a screen resolution of 1280 x 1024 pixels using E-Prime (2.0). Following the experiment, participants were asked to provide judgements of quality of contact towards Caucasian and East Asian people on a scale from 1 to 4 (1 – very superficial, 2 – rather superficial, 3 – rather intense, 4 – very intense, Wiese, 2012).

Procedure

The study consisted of a learning and a test phase. The learning phase comprised four blocks with 16 trials each. In each block, an equal number of Caucasian and East Asian faces (50% female respectively) were presented. Within each respective ethnic category, half of the faces were followed by an instruction to remember, the other half by an instruction to forget. Within each block, all trials were presented in random order. Each trial started with a fixation cross for 1,000 ms, followed by the face stimulus which remained on the screen for 750 ms. The stimulus was replaced by a mask (phase-randomised version of a face stimulus) presented for 250 ms to preclude visual aftereffects. Finally, participants were instructed via letter cues presented for 3,000 ms to either remember (“RRR”) or forget (“FFF”) the face previously presented (Figure 2.1).

During the test phase, and surprising to the participants, *all* 64 items from the learning phase (i.e., both TBR and TBF items) as well as 64 new items (again 50% female, 50% East Asian) were presented for 3,000 ms or, in case of faster responses, until the participants pressed a response key. Face stimuli were separated by a fixation cross (presented for 1,000 ms). For each face, participants had to indicate via left and right index finger key presses whether the face had been presented during learning or not. Stimuli were presented in random order, and the assignment of keypresses, the assignment of stimuli to first appear during learning or test, as well as the assignment of remember/forget instructions to learning phase stimuli was counterbalanced across participants.

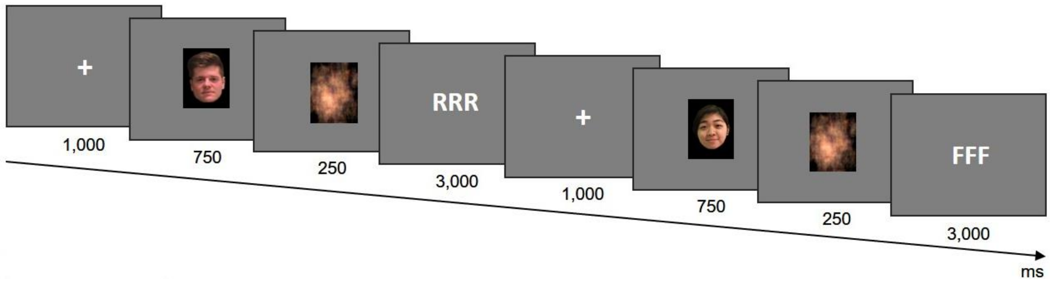

Figure 2.1 Exemplary trial structure of the learning phase of Experiments 1 and 2. Please note that for copyright reasons, images depicted here are not the pictures used in the experiment. Images are reprinted with full permission of the depicted persons.

Statistical analyses of recognition accuracy were performed using repeated measures analyses of variance (ANOVA) with factors ethnicity (Caucasian, East Asian) and instruction (remember, forget). Differences in participants' memory performance for own- and other-race faces was tested using a signal detection theory measure of sensitivity (*d*', e.g., Wickens, 2002). *d*' was computed by subtracting z-standardised false alarm rates from z-standardised hit rates for TBR faces for Caucasian and East Asian faces separately. Differences in *d*' for Caucasian and East Asian faces were analysed using paired samples t-tests. Moreover, correct rejections of Caucasian and East Asian faces presented as new items at test were again compared via paired samples t-tests.

Complementing these standard statistical procedures, we additionally adopted an estimation approach (see Cumming, 2012; Cumming & Calin-Jageman, 2017). In particular, we report point estimates of effect sizes (Cohen's *d*) and their corresponding 95% confidence intervals (CIs). As suggested by Cumming and Calin-

Jageman (2017), Cohen's *d* for paired samples t-tests was corrected for bias and calculated by using mean SD instead of the SD of the difference as the denominator (Cohen's d_{unb}). Calculation of effect sizes and confidence intervals was performed with ESCI (Cumming & Calin-Jageman, 2017).

2.2.2 Results

Contact Questionnaire

A paired samples t-test on quality of contact revealed significantly higher quality of contact to Caucasian (M = 3.333, 95% CI [3.10, 3.56]) than East Asian people (M = 1.861, 95% CI [1.58, 2.14]), $t(35) = 8.37$, $p < .001$, $M_{diff} = 1.472$, 95% CI [1.12, 1.83], Cohen's $d_{unb} = 1.898$, 95% CI [1.29, 2.57].

Performance

A repeated measures ANOVA with the within-subjects factor ethnicity (Caucasian, East Asian) and instruction (remember, forget) on hit rates resulted in a significant main effect of instruction, $F(1,35) = 7.61$, $p = .009$, $\eta^2_p = .179$, with superior memory for items cued to remember compared to items cued to forget. Importantly, this main effect was further qualified by a significant ethnicity x instruction interaction, $F(1,35) = 11.28$, $p = .002$, $\eta^2_p = .244$ (Figure 2.2a). Follow-up tests showed that the DF effect (R - F) was statistically significant for Caucasian faces, $t(35) = 3.72$, $p = .001$, $M_{diff} = 0.133$, 95% CI [0.06, 0.21], Cohen's d_{unb} = 0.789, 95% CI [0.34, 1.27], but not for East Asian faces, $t(35) = -0.41$, $p = .683$, M_{diff} = -0.010, 95% CI [-0.06, 0.04], Cohen's $d_{unb} = -0.062$, 95% CI [-0.36, 0.24] (Figure 2.2b).

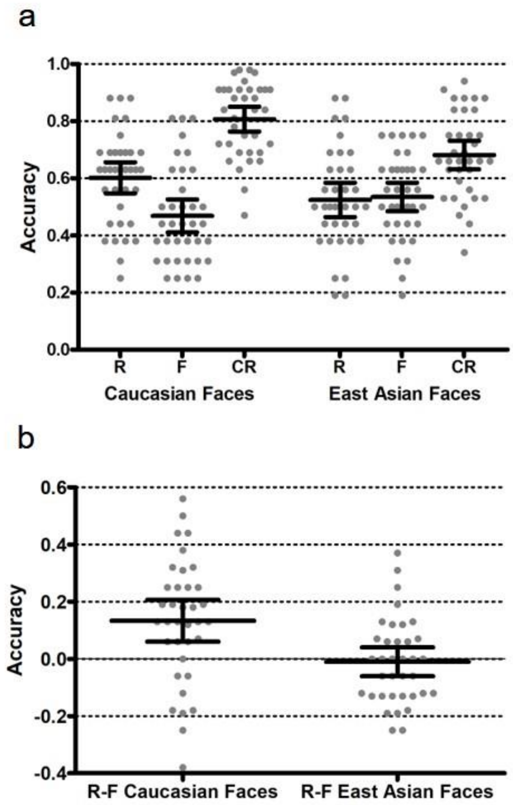

Figure 2.2 Results of Experiment 1. a) Mean accuracy for remember (R) and forget (F) items, as well as correct rejections (CR) for both Caucasian and East Asian faces. b) Mean DF effects (R-F) for Caucasian and East Asian faces respectively. Error bars depict 95% CI, grey dots show data from individual participants.

A paired samples t-test on correct rejection (CR) rates yielded significantly higher CR rates for Caucasian (M = .807, 95% CI [0.76, 0.85]) than for East Asian faces (M = .681, 95% CI [0.63, 0.73]), $t(35) = 4.85$, $p < .001$, $M_{\text{diff}} = 0.127$, 95% CI [0.07, 0.18], Cohen's $d_{\text{unb}} = 0.897$, 95% CI [0.48, 1.34] (Figure 2.2a). A paired samples t-test on d' revealed higher sensitivity for own-race Caucasian (M = 1.265, 95% CI [1.00, 1.53]) over other-race East Asian faces (M = 0.595, 95% CI [0.42, 0.77]), $t(35) = 6.23$, $p < .001$, $M_{\text{diff}} = 0.671$, 95% CI [0.45, 0.89], Cohen's d_{unb} = 0.989, 95% CI [0.61, 1.40].

2.2.3 Discussion

Experiment 1 investigated Caucasian participants' memory for own- and other-race faces. The main aim was to test the potential effect of motivation on the ORB by employing the DF paradigm. A significant DF effect was obtained for own-race faces, revealing better memory for items cued to remember compared to items cued to forget. This finding is in line with previous work (Fitzgerald et al., 2013; Goernert et al., 2011; Metzger, 2011; Paller et al., 1999) demonstrating that memory for faces can be intentionally modulated. Importantly, the DF effect was further found to depend on the ethnicity of the faces, as it was absent for other-race faces. This pattern would not be predicted by a socio-cognitive account that proposes motivational factors to influence memory for other-race faces. At the same time, it appears more in line with an expertise-based explanation of the ORB. As discussed in more detail above, the DF paradigm should motivate participants to process all faces until the TBR or TBF cue is presented. If motivation allows to adequately represent all faces until the cue is presented, effects of the memory cue should be similar for own- and other-race faces. If, however, perceptual expertise is substantially smaller for other-race faces, perceptual and cognitive processing stages before the presentation of the memory cue will not work as efficiently, resulting in a less accurate representation available when the TBR/TBF cue is shown. A less accurate representation will not only make it more likely that learned and novel faces are mixed up at test (as observed in the increased false alarm rate in the present experiment), but also in more similar performance for TBR and TBF items, as "forgotten" other-race faces will be more likely confused with representations of remembered faces.

Of note, Fitzgerald et al. (2013) investigated DF for other-race faces in Caucasian participants and observed significant effects for Asian and Black faces. However, as participants were only tested on other-race faces, this study precludes a comparison of DF effects for own- and other-race faces, and the calculation of a potential ORB. Importantly, the finding of a DF effect for other-race faces per se does not contradict our explanation of the present pattern of results, as one might assume that DF effects for own-race faces would have been even larger in the participants tested by Fitzgerald and colleagues (2013).

The results of Experiment 1 thus suggest that a modulation of face memory by the intention to remember is largely limited to those faces for which expertise has been acquired. Alternatively, however, it remains possible that differential DF effects for own- and other-race faces simply resulted from varying difficulty of the two stimulus sets, independent of perceptual expertise. In a next step, we therefore tested a group of East Asian participants with the same experiment. The finding of a DF effect for East Asian faces in East Asian participants would rule out a potential stimulus effect independent of expertise in Experiment 1.

2.3 Experiment 2

In Experiment 2, we tested a group of East Asian students who had been living in the UK for several months during which they had individuating contact to Caucasian people. This type of contact has previously been shown to be sufficient to reduce the ORB (e.g., Wiese et al., 2014). Our participants had thus acquired expertise with Caucasian faces before the experiment, but at the same time likely still perceived these faces as belonging to a social out-group. Therefore, if expertise is a prerequisite for the DF effect in face memory as suggested by Experiment 1, and our

East Asian sample had acquired expertise with both ethnic groups, we would predict DF effects for both own- and other-race faces. Similarly, if, as suggested by socio-cognitive accounts, motivation to individuate can modulate memory for both in- and out-group faces, and the experimental procedure encourages an initial motivation to individuate all faces, DF effects for both ethnic groups would be expected. Accordingly, Experiment 2 was not designed to distinguish between the two theoretical explanations of the ORB. If, however, the results of Experiment 1 were simply driven by differences in general difficulty of stimulus sets independent of expertise, we would expect to again find a DF effect for Caucasian, in this case other-race faces only.

2.3.1 Method

Participants

24 undergraduate and postgraduate students (18 – 31 years, $M = 20.83$, $SD = 3.13$, 21 female) with an East Asian ethnic background were tested. They had been living in the UK for 4 to 48 months prior to the experiment. All had normal or corrected-to-normal vision and were compensated analogously to Experiment 1. Participants gave written informed consent, and the study was approved by the local Ethics Committee.

Procedure

All stimuli and experimental parameters were identical to Experiment 1.

2.3.2 Results

Contact Questionnaire

A paired samples t-test showed significantly higher quality of contact to own-race East Asian (M = 3.125, 95% CI [2.71, 3.54]) compared to other-race Caucasian people (M = 1.958, 95% CI [1.62, 2.30]), $t(23) = 4.07$, $p < .001$, $M_{diff} = 1.167$, 95% CI [0.57, 1.76], Cohen's $d_{unb} = 1.248$, 95% CI [0.56, 2.00]. We note, however, that the effect size is substantially smaller as compared to Experiment 1.

Performance

An ANOVA with factors ethnicity (Caucasian, East Asian) and instruction (remember, forget) on hit rates yielded a significant main effect of instruction, $F(1,23) = 9.47$, $p = .005$, $\eta^2_p = .292$, again showing better memory for TBR than TBF items (Figure 2.3a). A significant main effect of ethnicity was not observed, $F(1,23) = 0.09$, $p = .763$, $\eta^2_p = .004$, and the ethnicity x instruction interaction failed to reach significance as well, $F(1,23) = 0.01$, $p = .966$, $\eta^2_p < .001$ (Figure 2.3b).

A paired samples t-test revealed comparable CR for Caucasian (M = 0.711, 95% CI [0.66, 0.76]) and East Asian faces (M = 0.748, 95% CI [0.70, 0.80]), $t(23) = -1.46$, $p = .158$, $M_{diff} = -0.037$, 95% CI [-0.09, 0.02], Cohen's $d_{unb} = -0.307$, 95% CI [-0.75, 0.12] (Figure 2.3a). Similarly, d' for Caucasian (M = 0.935, 95% CI [0.64, 1.23]) and East Asian faces (M = 1.042, 95% CI [0.80, 1.29]) did not differ significantly, $t(23) = -0.86$, $p = .399$, $M_{diff} = -0.108$, 95% CI [-0.37, 0.15], Cohen's $d_{unb} = -0.163$, 95% CI [-0.55, 0.22].

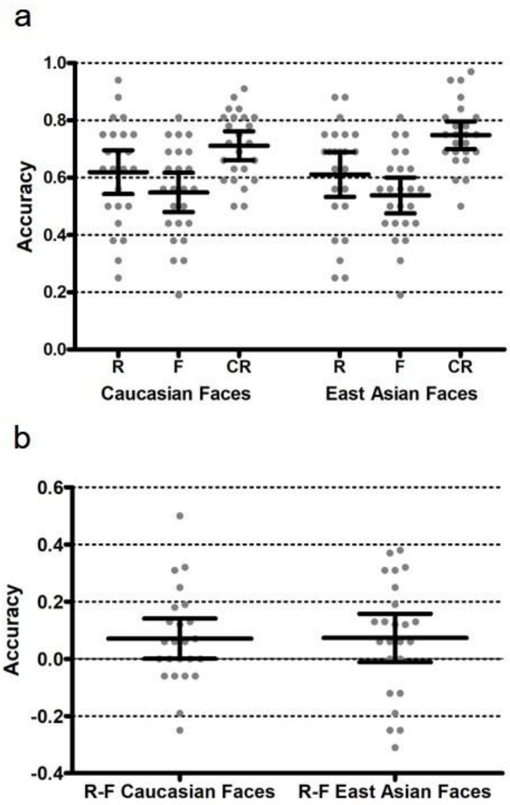

Figure 2.3 Results of Experiment 2. a) Mean accuracy for remember (R) and forget (F) items, as well as correct rejections (CR) for both Caucasian and East Asian faces. b) Mean DF effects (R-F) for Caucasian and East Asian faces respectively. Error bars depict 95% CI, grey dots show data from individual participants.

2.3.3 Discussion

Experiment 2 aimed at ruling out the possibility that the findings of Experiment 1 were driven by generally higher difficulty for the East Asian stimulus set rather than differences in expertise for own- versus other-race faces. As in Experiment 1, a significant DF effect was obtained. Unlike Experiment 1, however, this effect was not further qualified by ethnicity, and comparable DF effects for Caucasian and East Asian faces were observed. Similarly, an advantage for own- over other-race faces in correct rejection rates and *d*', as found for Caucasian participants in Experiment 1, was absent in the current sample of East Asian participants.

Together, the findings of Experiments 1 and 2 show that memory for faces of different ethnicities can be intentionally modulated with the DF procedure. Furthermore, the comparable DF effect for own- and other-race faces in East Asian participants in Experiment 2 suggests that Experiment 1's findings of significant DF effects for own- but not other-race faces were not driven by general differences in difficulty of the two stimulus sets. In a next step, the DF procedure was applied to a minimal group paradigm (see Bernstein, Young, & Hugenberg, 2007). Our aim was to investigate whether DF effects for in- but not out-group faces occur when group status is determined exclusively by social factors and cannot be affected by perceptual expertise.

2.4 Experiment 3

Although the previous two experiments ruled out differences in general stimulus difficulty and motivation as likely explanations, it remains possible that a socio-cognitive factor other than motivation to individuate underlies the differential DF observed in Experiment 1. More specifically, socio-cognitive accounts suggest that other-race faces are automatically classified as belonging to a social out-group and then processed at a categorical rather than individual level (Sporer, 2001). While the CIM suggests that motivation to individuate is capable of modulating the processing of out-group faces, the procedure in the DF paradigm might not be sufficient to elicit this process. If so, less accurate representations of out-group faces would be created. This in turn might still explain the findings of Experiment 1 without necessarily assuming differences in perceptual expertise as the underlying mechanism.

In an attempt to test this possibility, we examined DF for purely social in- and out-group faces. Such in- and out-groups (e.g., own- versus other university affiliation) do not systematically differ with respect to facial characteristics, and indeed face stimuli are randomly assigned to these groups. Any difference in memory is then highly likely driven by factors related to social group membership and cannot be explained in terms of differential perceptual expertise. Previous research reported that labelling (own-race) faces as belonging to the participant's own versus a different university is sufficient to elicit a memory advantage for in- versus out-group faces (Bernstein et al., 2007). The same pattern was observed for experimentally created minimal groups (i.e., randomly assigning participants to a "red" vs. "green" personality type).

To further distinguish between automatic categorisation versus individuation of in- and out-group faces on the one hand and an explanation on the basis of perceptual expertise on the other hand, we examined DF for faces belonging to purely social in- versus out-groups which did not differ with respect to expertise. If the pattern of clear DF effects for own- but not other-race faces observed in Experiment 1 was driven by social categorisation, a similar result with DF effects for purely social in- but not out-group faces would be expected in Experiment 3. If, however, the pattern of Experiment 1 resulted from perceptual expertise, we would expect comparable DF effects for purely social in- and out-group faces.

2.4.1 Method

Participants

32 undergraduate and postgraduate students (18 – 30 years, M = 20.31, SD = 3.04, 29 female) took part in the study. All had normal or corrected-to-normal vision, and were compensated as described for Experiment 1. The study was approved by the local Ethics Committee.

Stimuli and Apparatus

The stimulus set comprised 128 colour photographs of unfamiliar Caucasian faces (50% female). Photographs were taken from various face data bases (see Wiese et al., 2014). Selection criteria and editing of images were identical to Experiment 1. Moreover, ten items were randomly selected from a personality inventory (NEO-PI-R, Costa & McCrea, 1992).

Procedure

The procedure was identical to Experiment 1 except for the following changes. At the beginning of the experimental session, participants completed a short personality questionnaire. Items (e.g., I laugh easily; I try to perform all tasks assigned to me conscientiously; I strive for excellence in everything that I do) were presented individually on a screen until participants typed in their response, with keys assigned to five possible response options (strongly disagree, disagree, neutral, agree, and strongly agree). Participants were then told that they were a “red” or “green” personality. Unbeknown to the participants, the assignment of participants to these categories was completely arbitrary and unrelated to the answers given in the questionnaire, which were de facto not analysed. We chose veridical items from a commonly employed questionnaire to corroborate authenticity of the procedure. To further increase credibility, participants were given red or green wristbands to wear during the experiment and received exactly the same information about their groups as originally provided by Bernstein et al. (2007, p.710).

During the learning phase of the following recognition memory experiment, a red or green frame was placed around the face stimulus (with equal probability), which indicated whether the face belonged to the participants' in- or out-group with respect to "personality type" (Figure 2.4). Assignment of red or green frames to the face stimuli was counterbalanced across participants. Additionally, as in Experiment 1, we counterbalanced the assignment of stimuli to learning and test phase of the experiment, and the assignment of remember/forget instructions to the face stimuli within the learning phase set.

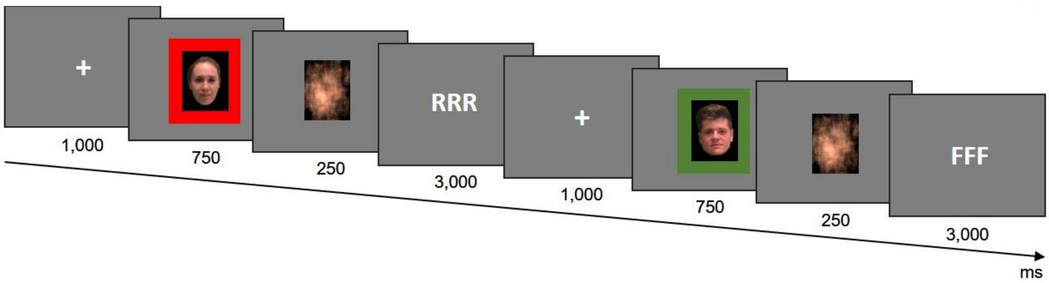

Figure 2.4 Exemplary trial structure of the learning phase of Experiment 3. Please note that for copyright reasons, images depicted here are not the pictures used in the experiment. Images are reprinted with full permission of the depicted persons.

2.4.2 Results

Performance

A repeated measures ANOVA with factors group membership (in-group, out-group) and instruction (remember, forget) on hit rates yielded a significant main effect of instruction, $F(1,31) = 4.25$, $p = .048$, $\eta^2_p = .121$, with higher accuracies for TBR as opposed to TBF items. Neither the main effect of group membership, $F(1,31) = 0.29$, $p = .596$, $\eta^2_p = .009$, nor the group membership x instruction interaction, $F(1,31) = 1.79$, $p = .191$, $\eta^2_p = .055$, were statistically significant (Figure 2.5a, b).

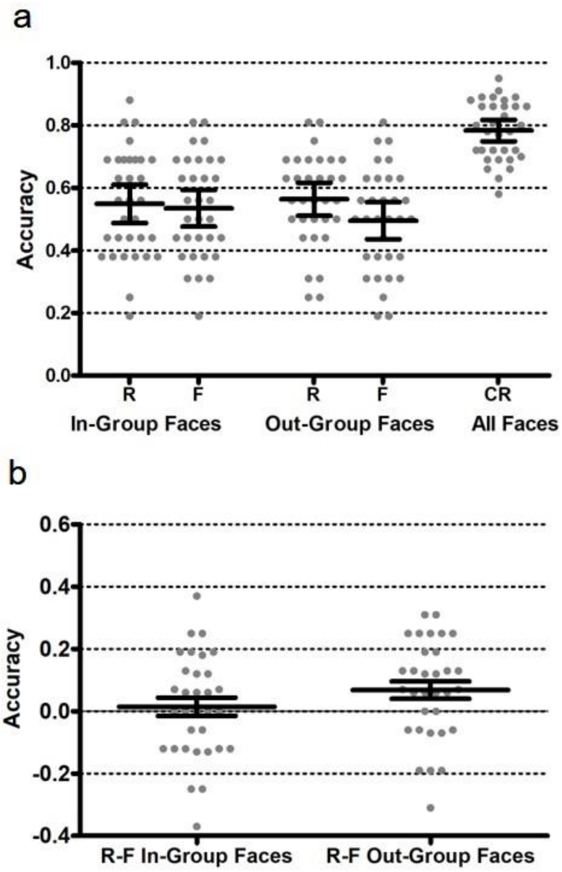

Figure 2.5 Results of Experiment 3. a) Mean accuracy for remember (R) and forget (F) items, for in- and out-group faces respectively, and the CR rate. b) Mean DF effects (R-F) for in- and out-group faces. Error bars depict 95% CI, grey dots show data from individual participants.

We additionally conducted a t-test comparing the hit rates for in- and out-group TBR faces to assess whether the manipulation of group membership was effective for TBR faces, the condition which is closest to the original procedure reported by Bernstein et al. (2007). Hit rates for TBR in- and out-group faces did not differ significantly, $t(31) = -0.48$, $p = .635$, $M_{diff} = -0.014$, 95% CI [-0.08, 0.05], Cohen's d_{unb} = -0.088, 95% CI [-0.46, 0.28].

CR rate (M = 0.783, 95% CI [0.75, 0.82], Figure 2.5a) was comparable to Experiments 1 and 2. A paired samples t-test on *d*' revealed comparable performance for in- (M = 0.965, 95% CI [0.78, 1.15]) and out-group faces (M = 0.996, 95% CI [0.80, 1.19]), $t(31) = -0.37$, $p = .711$, M_{diff} = -0.034, 95% CI [-0.20, 0.14], Cohen's d_{unb} = -0.056, 95% CI [-0.36, 0.25].

2.4.3 Discussion

Experiment 3 investigated DF effects for purely social in- versus out-group faces to further distinguish between socio-cognitive and expertise-based explanations of the results obtained in Experiment 1, which found DF for own- but not other-race faces. Our analysis revealed a significant main effect of memory instruction, with more accurate memory for TBR than TBF faces. Unlike Experiment 1, this DF effect did not interact with social in- and out-group category, reflecting in principle the pattern expected under an expertise-based explanation of the ORB.

At variance with Bernstein et al. (2007), we did not find evidence for differential recognition of purely social in- versus out-group faces. Therefore, one might argue that the manipulation of group membership was unsuccessful, and it may therefore seem meaningless to test for differential DF for in- and out-group faces. The failure to replicate the effect observed by Bernstein et al. (2007) was unexpected, in particular because we followed their design as closely as possible, using the same basic procedure and identical instructions. However, we aknowledge that the additional DF manipulation during learning might have increased processing demands compared to Bernstein et al. (2007). At the same time, the DF procedure gave rise to an ORB in Experiment 1. Accordingly, although it is possible that the group membership manipulation might have increased task demands in the present experiment, this would suggest that a memory bias resulting from a minimal group paradigm is generally less robust than the ORB (see also Herzmann & Curran, 2013). An alternative, and not mutually exclusive, explanation could be that group membership was indicated by an additional cue (i.e., coloured frame) that was external to the face (whereas race is inherent in the face). This frame may, at least to a certain extent, have directed attention away from the face given that it needed to be encoded along with the face, resulting in a somewhat weaker representation for in- and out-group faces compared to those formed for own-race faces in Experiment 1. While speculative at present, this may perhaps explain why the DF effect in Experiment 3 was overall substantially smaller compared to the effect observed for own-race faces in Experiment 1.

In Experiment 4, we undertook a further attempt to examine whether the results of Experiment 1 reflected automatic categorisation into in- or out-groups or differences in perceptual expertise. This time, we investigated DF effects for own- and other-gender faces.

2.5 Experiment 4

In Experiment 3, we only observed small DF effects for in-and out-group faces. In addition, and at variance with Bernstein et al. (2007), we did not find evidence for a successful manipulation of group membership. Therefore, it could be argued that a failure to provide evidence for a social categorisation manipulation in the first place makes it pointless to test hypotheses regarding DF for in- and out-group faces, respectively.

In Experiment 4, a further attempt was undertaken to investigate whether Experiment 1's finding of DF for own- but not other-race faces resulted from automatic categorisation into in- or out-groups or differential perceptual expertise. To this end, we investigated DF for own- and other-gender faces in female participants. The own-gender bias (for a review, see Herlitz & Loven, 2013) refers to better memory for own- than for other-gender faces and is often found to be reliable in female, but not in male, participants (e.g., Wiese & Schweinberger, 2018), although the exact pattern of results is not entirely consistent across studies (e.g., Steffens, Landmann, & Mecklenbräuker, 2013; Wolff, Kemter, Schweinberger, & Wiese, 2014; Wright & Sladden, 2003). The own-gender bias is mostly considered to be unrelated to expertise as most people in Western societies have equal amounts of contact with male and female faces (for an alternative developmental framework, see Herlitz & Loven, 2013).

As in Experiment 3, we reasoned that if the result of DF for own- but not other-race faces in Experiment 1 was driven by an automatic categorisation of faces into in- and out-groups, we would expect to find DF for own- but not other-gender faces. By contrast, if the pattern of results obtained in Experiment 1 reflected differential expertise with own- and other-race faces, DF effects would be expected for both own- and other-gender faces.

2.5.1 Method

Participants

36 female Caucasian undergraduate and postgraduate students (18 – 28 years, M = 19.56, SD = 1.82) consented to take part in the experiment. All had normal or

corrected-to-normal vision, and were compensated as described for Experiment 1. The study received ethical approval from the local ethics committee.

Stimuli and Apparatus

The stimulus set used in this experiment was identical to that used in Experiment 3. However, as this experiment investigated DF for own- and other-gender faces, both the personality inventory and the coloured frames were no longer required.

Procedure

The procedure was identical to that of Experiment 1 except that all stimuli now depicted Caucasian faces and gender of the stimuli replaced ethnicity as a factor in all of the analyses.

2.5.2 Results

Performance

A repeated measures ANOVA with the within-subjects factors gender (female, male) and instruction (remember, forget) on hit rates revealed a significant effect of instruction, $F(1,35) = 35.02$, $p < .001$, $\eta_p^2 = .500$, with better performance for TBR compared to TBF faces (Figure 2.6a). While the main effect gender was not significant, $F(1,35) = 0.96$, $p = .333$, $\eta_p^2 = .027$, the gender x instruction interaction approached significance, $F(1,35) = 3.43$, $p = .072$, $\eta_p^2 = .089$. Post-hoc comparisons revealed significant DF effects for female, $t(35) = 6.49$, $p < .001$, $M_{diff} = 0.163$, 95% CI [0.11, 0.21], Cohen's $d_{unb} = 1.080$, 95% CI [0.68, 1.52], and male faces, $t(35) =$

3.29, $p = .002$, $M_{\text{diff}} = 0.101$, 95% CI [0.04, 0.16], Cohen's $d_{\text{unb}} = 0.620$, 95% CI [0.22, 1.04], with larger effect sizes for female faces (Figure 2.6b). A comparison of hit rates for TBR female and male faces revealed a trend for better memory for TBR female relative to male faces, $t(35) = 1.93$, $p = .062$, $M_{\text{diff}} = 0.054$, 95% CI [-0.01, 0.11], Cohen's $d_{\text{unb}} = 0.324$, 95% CI [-0.02, 0.67].

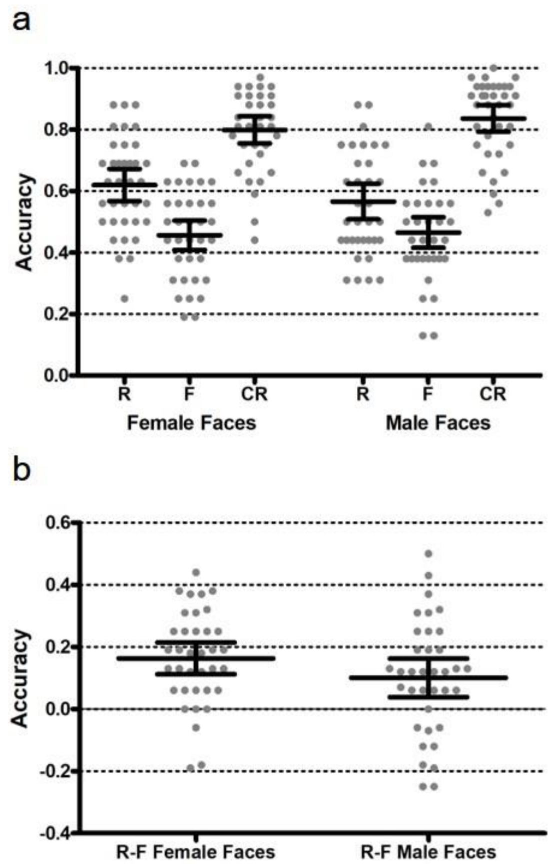

Figure 2.6 Results of Experiment 4. a) Mean accuracy for remember (R) and forget (F) items, as well as correct rejections (CR) for both female and male faces. b) Mean DF effects (R-F) for female and male faces. Error bars depict 95% CI, grey dots show data from individual participants.

A paired samples t-test on CR revealed comparable performance for female ($M = 0.800$, 95% CI [0.76, 0.84]) and male faces ($M = 0.836$, 95% CI [0.79, 0.88]), $t(35) = -1.75$, $p = .089$, $M_{\text{diff}} = -0.037$, 95% CI [-0.08, 0.01], Cohen's $d_{\text{unb}} = -0.279$, 95% CI [-0.61, 0.04] (Figure 2.6a). Similarly, *d*’ for female (M = 1.263, 95% CI [1.05, 1.48]) and male faces (M = 1.300, 95% CI [1.06, 1.54]), $t(35) = -0.34$, p = .736, M_{diff} = -0.035, 95% CI [-0.24, 0.17], Cohen’s d_{unb} = -0.050, 95% CI [-0.35, 0.25], did not differ significantly.

2.5.3 Discussion

In Experiment 4, we again found significant DF effects, reflecting better memory for TBR compared to TBF faces. In contrast to Experiment 1, the present experiment revealed substantial DF for both own- and other-gender faces, reflecting the pattern of results which would be predicted under a perceptual expertise-based explanation of the ORB. As both own- and other-gender faces in Experiment 4 were from the participants’ own race, this theorerical account would assume clear effects for the two face categories if DF were driven by expertise. The current pattern of results would not, however, be expected from a socio-cognitive perspective. If automatic categorisation resulted in less pronounced individuation of social out-group faces (e.g., Hugenberg et al., 2010; Sporer, 2001) and therefore less accurate representations for these stimuli, we would have expected a result similar to Experiment 1, in which ethnic in-group faces elicited a DF effect, but out-group faces did not.

In the present study, an own-gender memory bias was absent in female participants in both accuracies and *d*’, which is reminiscent of the finding of comparable memory for in- and out-group faces in Experiment 3. We have noted above that the failure to find differential memory for in- and out-group faces might mean that the manipulation of group membership was unsuccessful and that it might therefore be inadequate to expect in- and out-group faces to be differentially affected by DF. Given the absence of an own-gender bias in the present experiment, a similar argument could in principle be made here as well. However, it appears less plausible to assume that the gender of the faces was not processed relative to the arbitrary social category used in Experiment 3. Of note, and in contrast to Experiment 3, the present study revealed a trend for a significant interaction, pointing to somewhat more pronounced DF for own- relative to other-gender faces. Moreover, this trend seems to be mostly driven by higher hit rates for female versus male faces in the TBR condition. This may be taken to suggest that gender was a sufficiently salient dimension to elicit social categorisation, as own- and other-gender faces were somewhat differentially remembered. However, we acknowledge that the evidence for a successful categorisation of own- and other-gender faces into in- and out-groups is not particularly strong in the present experiment, and that further reseach is needed to increase confidence in the present results.

In the previous paragraph, it has tentatively been suggested that higher hit rates for female compared to male TBR faces indicates social categorisation of faces into in- and out-groups. At the same time, we have argued that the finding of substantial DF for both own- and other-gender faces supports an expertise-based explanation of the results obtained in Experiment 1. At a first glance, these suggestions might be seen as being in opposition. We note, however, that while DF in Experiment 1 was evident for own-race faces, it was very clearly absent for other-race faces (Figure 2.2b). In Experiment 4, both own- and other-gender faces gave rise to DF. We therefore conclude that while, as suggested above, evidence for a successful social categorisation is not particularly strong at present, the finding of DF for both own- and other-gender faces supports our previous suggestion that a modulation of face memory by intentional processes is limited to faces we have expertise with.

Interestingly, although Experiments 3 and 4 used the same stimulus set, DF effects were substantially more pronounced in Experiment 4. As discussed above, this might reflect increased processing demands in Experiment 3 due to social group membership being indicated by coloured frames placed around the face images. By contrast, Experiment 4 used a more “natural” social category (i.e., gender) that, similar to race, is derived from the face itself.

2.6 Experiment 5

Experiments 1 to 4 all showed significant DF effects. However, a significant interaction of DF with face category has so far only been detected in Experiment 1. We interpreted this finding to reflect that DF cues can only become effective when participants have sufficient expertise with the respective face category. It could also be argued, however, that a failure to find DF effects for other-race faces in Experiment 1 might be related to chance level performance for TBR and TBF other-race faces. While CR were generally well above 50% and thus provide evidence against this possibility, we reasoned it would nonetheless be beneficial to replicate the findings of Experiment 1. We therefore conducted another experiment to investigate DF of own- and other-race faces in Caucasian participants. To address the above concerns, we decreased task difficulty by reducing the number of stimuli in each learning block. Moreover, we only tested female participants with female face stimuli, as this combination has been shown to result in highest accuracies in a recent meta-analysis (Herlitz & Loven, 2013).

As these changes did not affect our participants' increased level of expertise with own- relative to other-race faces, we expected to replicate the result of Experiment 1. In particular, we hypothesised that Caucasian participants with limited other-race contact would demonstrate DF for own- but not other-race faces. This finding would further strengthen our previous suggestion that a modulation of memory by the intention to remember is largely restricted to faces for which a substantial amount of perceptual expertise has been acquired.

2.6.1 Method

Participants

36 female undergraduate and postgraduate students (18 – 43 years, *M* = 22.08, *SD* = 5.61) with a Caucasian ethnic background took part in the experiment and received course credit for participating. All had normal or corrected-to-normal vision and were compensated as described for Experiment 1. The study was approved by the local ethics committee.

Stimuli and Apparatus

96 colour photographs of unfamiliar faces were used as stimuli which were taken from various databases (see Wiese et al., 2014). As in Experiment 1, half of these showed Caucasian faces, while the other half depicted East Asian faces. At variance with Experiments 1 to 4, only female faces were shown. Participants were again required to provide ratings of quality of contact with Caucasian and East Asian people after the main experiment (Wiese, 2012).

Procedure

The procedure was identical to Experiment 1 except that we reduced the number of stimuli presented in each block from 16 to 12, resulting in a total of 48 stimuli presented during learning. At test, these images were presented in random order, intermixed with 48 new items (50% Caucasian).

2.6.2 Results

Contact Questionnaire

A paired samples t-test on quality of contact revealed significantly higher quality of contact to Caucasian (M = 3.556, 95% CI [3.32, 3.79]) than East Asian people (M = 1.750, 95% CI [1.48, 2.02]), $t(35) = 10.18$, $p < .001$, $M_{diff} = 1.806$, 95% CI [1.45, 2.17], Cohen's $d_{unb} = 2.348$, 95% CI [1.67, 3.12].

Performance

A repeated measures ANOVA with the within-subjects factors ethnicity (Caucasian, East Asian) and instruction (remember, forget) on hit rates revealed a significant main effect of instruction, $F(1,35) = 4.39$, $p = .044$, $\eta_p^2 = .111$, indicative of higher accuracies for TBR than TBF faces (Figure 2.7a). Crucially, we also observed a significant ethnicity x instruction interaction, $F(1,35) = 8.66$, $p = .006$, $\eta_p^2 = .198$. Post-hoc comparisons yielded a significant DF effect for Caucasian faces, $t(35) = 3.38$, $p = .002$, $M_{diff} = 0.107$, 95% CI [0.04, 0.17], Cohen's $d_{unb} = 0.570$, 95% CI [0.22, 0.94], but not for East Asian faces, $t(35) = -0.25$, $p = .803$, $M_{diff} = -0.008$, 95% CI [-0.07, 0.05], Cohen's $d_{unb} = -0.038$, 95% CI [-0.34, 0.27] (Figure 2.7b).

A paired samples t-test yielded significantly higher CR for Caucasian faces (M = 0.796, 95% CI [0.76, 0.83]) than for East Asian faces (M = 0.735, 95% CI [0.69, 0.79]), $t(35) = 2.18$, $p = .036$, $M_{diff} = 0.060$, 95% CI [0.01, 0.12], Cohen's $d_{unb} = 0.469$, 95% CI [0.03, 0.92] (Figure 2.7a). In addition, a paired samples t-test on d' revealed significantly higher sensitivity for Caucasian (M = 1.384, 95% CI [1.13, 1.64]) than for East Asian faces (M = 0.857, 95% CI [0.64, 1.08]), $t(35) = 4.45$, $p < .001$, $M_{diff} = 0.527$, 95% CI [0.29, 0.77], Cohen's $d_{unb} = 0.733$, 95% CI [0.37, 1.12].

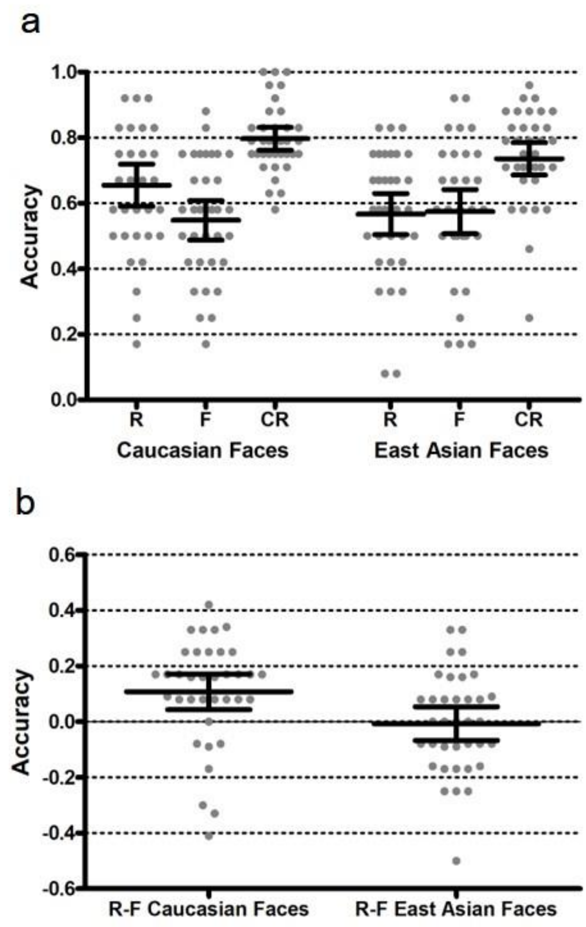

Figure 2.7 Results of Experiment 5. a) Mean accuracy for remember (R) and forget (F) items, as well as correct rejections (CR) for both Caucasian and East Asian faces. b) Mean DF effects (R-F) for Caucasian and East Asian faces respectively. Error bars depict 95% CI, grey dots show data from individual participants.

2.6.3 Discussion

Experiment 5 fully replicated the results of Experiment 1. Most importantly, a DF effect was again only observed for own-race faces, which further supports our earlier suggestion that a modulation of face memory is only possible when participants have acquired substantial expertise with a given class of faces.

To address the possibility that a failure to obtain DF for other-race faces in Experiment 1 might have resulted from low performance, we reduced the number of stimuli in Experiment 5 to decrease task difficulty. As a result, overall higher hit rates were observed compared to Experiment 1, for both own- and other-race faces. Yet, as in Experiment 1, we still did not find any evidence of DF for other-race faces. This clearly shows that a failure to find DF in Experiment 1 cannot be accounted for by chance performance. Rather, the present results strengthen our previous suggestion that a modulation of face memory appears to be limited to face categories we have substantial perceptual expertise with.

In Experiment 5, DF for own-race faces was found to be slightly less pronounced than in Experiment 1, albeit still significantly different from zero (see Figure 2.7b). This is unsurprising given that memory load was reduced overall which will arguably make it more likely for a given face to be remembered at test, irrespective of the DF cue it was paired with, thereby attenuating the DF effect.

2.7 General Discussion

The current series of experiments investigated DF of in- and out-group faces to test predictions derived from perceptual expertise and socio-cognitive accounts of the ORB. We observed distinct patterns of DF effects in five experiments. While

Caucasian participants in Experiments 1 and 5 demonstrated DF for own- but not for other-race faces, East Asian participants with considerable expertise for the ethnic out-group showed comparable DF for own- and other race faces in Experiment 2. Experiment 3 and 4 revealed DF effects which did not differ significantly between purely social in- and out-group faces. As discussed below, these results are well in line with a perceptual expertise account of the ORB, but are difficult to integrate with socio-cognitive explanations.

An expertise-based explanation of the present findings can easily be integrated with the MDFS framework (Valentine, 1991). Given that perceptual expertise for other-race faces is reduced, MDFS postulates that their representations will be more similar to each other and clustered more densely in face space than own-race face representations (see Figure 2.8a). Accordingly, in the test phases of recognition memory experiments, learned and novel other-race faces were more similar than learned and novel own-race faces, resulting in increased false alarm rates for the former category (Figure 2.8c). Importantly, in the present study, participants were additionally asked to remember half and to forget the other half of the faces presented during learning. Again, TBR and TBF other-race faces were perceptually more similar to each other than the respective own-race faces. Accordingly, if the TBF cue was successful and participants forgot the respective other-race item (Figure 2.8b), it would have nevertheless been projected to a face space location densely clustered with other representations when presented at test. Participants then more likely endorsed this face as “old”, although it was de facto confused with a neighbouring face representation (Figure 2.8d). This in turn substantially reduced differences between TBR and TBF other-race faces, and therefore resulted in small or even absent DF effects. Of note, the mechanism described here gives rise to a paradoxical effect: Other-race TBF faces, despite de facto being forgotten, will be "falsely remembered" as they are confused with a close neighbour.

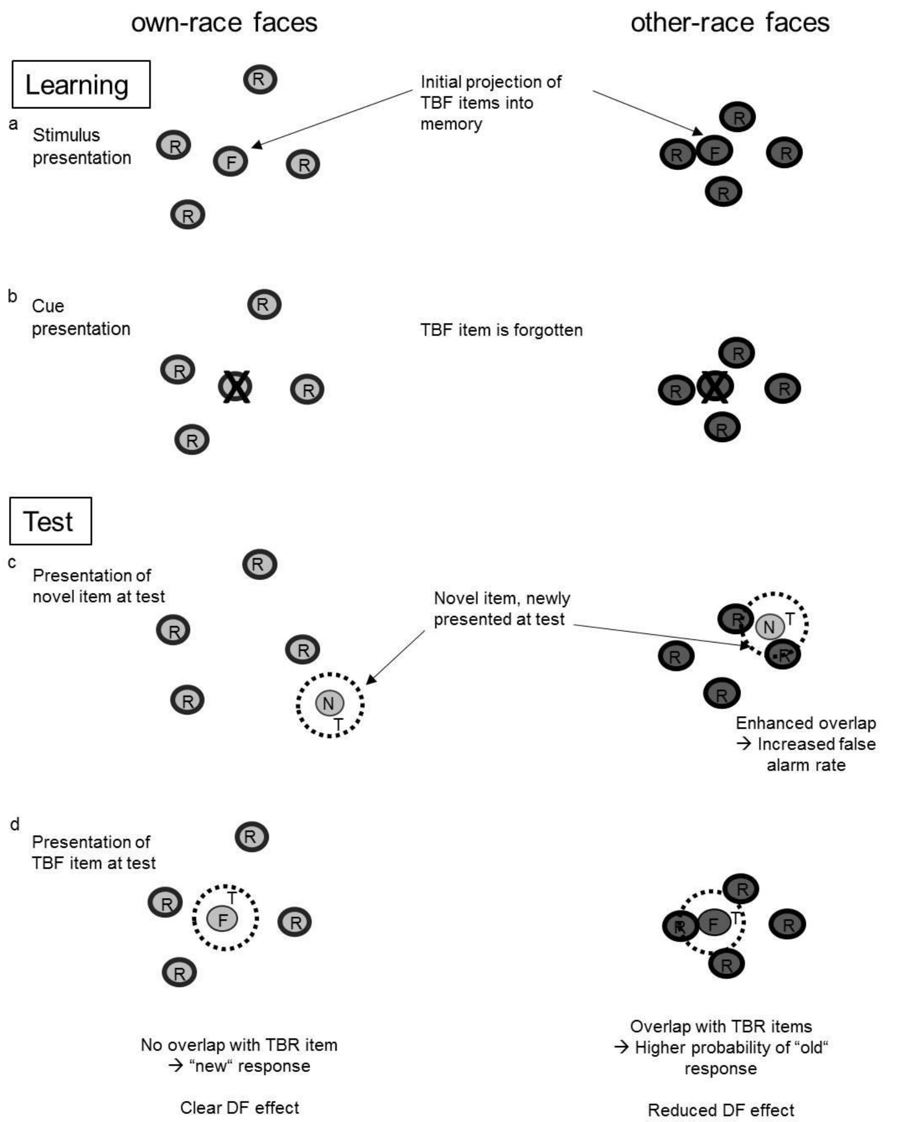

Figure 2.8 Schematic illustration for differential DF effects for own- and other-race faces. See text for a more detailed description.

Accordingly, MDFS provides a viable framework to explain the present results, although alternative expertise-based explanations, e.g., in terms of holistic processing, might also be possible. The present series of experiments was designed to test the contribution of socio-cognitive and motivational factors to the ORB, and therefore cannot distinguish between the various expertise-based accounts.

Moreover, it has to be noted that the MDFS framework itself has been criticised. Although MDFS offers an intuitive explanation for a number of findings in face recognition research, such as memory advantages for distinctive and caricatured faces (e.g., Benson & Perrett, 1994; Lee, Byatt, & Rhodes, 2000), these accounts (often) fail to specify the exact number and nature of dimensions of the assumed space (but see Calder, Burton, Miller, Young, & Akamatsu, 2001). Typically, MDFS approaches derive their assumptions from illustrations of a two- or three-dimensional space. However, it can be shown mathematically that many of these assumptions do not hold in a space with a sufficiently large number of dimensions to accurately represent individual faces (Burton & Vokey, 1998). Importantly for the present purpose, the argument we offer here can be made without explicit reference to a multi-dimensional face space. Instead, our argument is based on the fundamental idea that faces that are perceived as similar are more likely to be mistaken for one another. In the present context, this will result in enhanced confusion among TBR and TBF other-race faces and thus reduced DF effects.

Experiments 2 to 5 were designed to test alternative explanations for the differential DF effect in our first experiment. First, one could argue that our finding of DF for own- but not other-race faces simply resulted from overall differences in difficulty between the two sets of stimuli, or from our set of East Asian faces being physically more similar compared to the Caucasian face set. These concerns were addressed in Experiment 2 which revealed comparable DF for own- and other-race faces in East Asian participants using the same stimuli as in Experiment 1.

Second, one might argue that the pattern observed in Experiment 1 was driven by automatic categorisation processes based on out-group-defining features (Sporer, 2001). Accordingly, other-race faces might have been automatically classified as belonging to an out-group and were thus not further processed at an individual level, generating the pattern of results observed in Experiment 1. This explanation would be hard to reconcile with the findings of Experiment 2, as Caucasian faces were probably still out-group faces for our East Asian participants, despite enhanced levels of contact. Nevertheless, to rule out this possibility also for Caucasian participants, Experiments 3 and 4 investigated DF for faces belonging to different social groups which did not differ with respect to expertise. We found a DF effect which did not interact with social group membership in Experiment 3, and also clear DF effects for own- and other-gender faces in Experiment 4, rendering it unlikely that social categorisation was driving the effect in Experiment 1. Instead, these findings are more in line with an expertise-based explanation of DF for own- and other-race faces. However, this conclusion should be met with caution given that we did not find unequivocal evidence for social categorisation in the present experiments.

Finally, it might be argued that the absence of DF for other-race faces in Experiment 1 simply resulted from guessing, as performance for this face category was generally low. To rule out this possibility, overall task difficulty was reduced in Experiment 5. However, despite a general increase in accuracy, the results of Experiment 1 were fully replicated, suggesting that the lack of DF for other-race faces cannot be accounted for by chance performance.

With respect to the motivational component of the DF instruction, we have suggested that the repeatedly presented TBR and TBF cues should motivate participants to initially encode all faces. Alternatively, it could be argued that the DF procedure generally reduces motivation to individuate the items given that half of the faces are, in fact, paired with a cue to forget during learning. We do not think this is likely, and both previous work and the present results provide evidence against this suggestion. From a theoretical perspective, as detailed in the introduction, a TBF cue is thought to stop rehearsal and to actively inhibit the previously presented item (e.g., Anderson & Hanslmayr, 2014; Basden et al., 1993, Nowicka et al., 2009). Both of these mechanisms arguably require motivation to initially process the presented material to be effective. Critically, by the time the cues are presented, the face stimulus has been removed from the screen and only its memory representation is available to the participant. In addition, in the present experiments, all faces were followed by a mask to prevent any visual aftereffect. Accordingly, if motivation was low and the resulting representations of the stimuli weak by the time the cue was presented, it would be inefficient to actively modulate this already weak representation. As a consequence, the resulting DF effects would arguably be moderate at best. However, we observed quite substantial DF effects (d_{unb} = 0.789 for own-race faces in Experiment 1, d_{unb} = 1.080 for own-gender faces in Experiment 4). Thus, it appears unlikely that, in general, the DF procedure reduces motivation to individuate the face stimuli.

On a more general note, we acknowledge that throughout the paper references have been made to paradigms which used individuating instructions to study the mechanisms underlying the ORB (e.g., Hugenberg et al., 2007). In the introduction, we have argued that DF may be more motivating than typical recognition memory paradigms, which might represent an interesting parallel to the instruction manipulation. At the same time, we acknowledge that DF is quite different from the instruction manipulation. In the latter, participants receive information about the ORB prior to the experiment and are instructed to attend more to other-race faces and individuating features in them. In the DF paradigm, in contrast, participants are only instructed to follow the R and F cues, while no information is given with respect to how attention should be divided between own- and other-race faces. This may explain why the present results are somewhat different from those found in paradigms using individuating instructions. In particular, previous studies have reported that individuating instructions given to participants prior to the experiment can eliminate the ORB (Hugenberg et al., 2007; Rhodes et al., 2009; Young et al., 2010) while in the present study no evidence of DF for other-race faces was observed. However, it may well be that putting *more* effort into individuating other-race relative to own-race faces is needed to overcome the ORB, and that the lack of DF for other-race faces was due to the fact that the DF paradigm does not explicitly require this.

As detailed in the introduction, however, evidence for individuating instructions is not as clear-cut as originally thought. In fact, it has recently been suggested that instruction effects depend on the specific context in which the ORB is investigated (Wan et al., 2015). The authors reported no effect of instruction in Caucasian and East Asian participants tested with Caucasian and East Asian faces in Australia and concluded that in this context, the ORB resulted entirely from differences in perceptual expertise. An intriguing question then would be whether DF for other-race faces in Caucasian participants would be observable in a different cultural setting. For instance, one might speculate that White US participants show DF effects for African-American faces, as they presumably have considerably more expertise with such faces than our Caucasian participants had with East Asian faces. Accordingly, if in a given context perceptual expertise for out-group faces is relatively low (as for other-race faces in the present Experiments 1 and 5), this lack of perceptual expertise drives the bias in face memory (see also Stahl, Wiese, &

Schweinberger, 2010; Wiese et al., 2014). If, however, expertise for out-group faces is relatively high (e.g., in the setting studied by Hugenberg and colleagues), motivation may well contribute substantially to the observed memory differences for own- and other-race faces.

In conclusion, both Caucasian (Experiments 1 and 5) and East Asian participants (Experiment 2) showed DF for the respective own-race faces. Additionally, East Asian participants demonstrated DF for other-race Caucasian faces, which was highly similar to the respective effect for own-race faces. Given that our East Asian sample had acquired substantial expertise with Caucasian faces while living in the UK, whereas our Caucasian participants did not have comparable expertise with East Asian faces, our results suggest that perceptual expertise is a prerequisite for a modulation of face memory by intentional processes or motivation. As recent socio-cognitive models of the ORB posit the exact opposite relationship between the two concepts, namely that expertise is only fully employed for faces perceivers are motivated to individuate, the present results are not in line with these suggestions. By contrast, perceptual expertise accounts offer a plausible interpretation of the present findings.

3 Individuating instructions and the ORB

Socio-cognitive theories of the own-race bias (ORB) propose that reduced recognition of other-race faces results from the failure to attend to individuating information in these faces during encoding. In line with this suggestion, individuating instructions that explicitly inform participants about the ORB and instruct them to pay close attention to other-race faces during learning can attenuate or even eliminate the ORB. In the present experiment, we investigated the effect of individuating instructions on the ORB in recognition memory and encoding-related event-related potentials (ERPs) that contrast neural activity related to subsequently remembered and forgotten items (ERP Dm effects). In line with a socio-cognitive account, individuating instructions reduced the ORB in recognition memory, suggesting that increased attention to other-race faces can improve recognition. At the same time, individuating instructions increased ERP Dm effects for other-race faces, indicating that successful learning may require additional effort. Therefore, the present results suggest that although instructions to individuate can improve other-race face recognition, additional effort is required to reduce difficulties resulting from a lack of perceptual expertise. This indicates that compensating for reduced experience with other-race faces is possible to some extent but requires additional resources.

3.1 Introduction

Face recognition is a crucial skill that is central to social interactions and we are remarkably good at it. However, not all faces are recognised equally well. One of the most widely researched phenomena in the face memory literature is the own-race bias (ORB, or other-race effect), the well-documented finding that people more accurately remember faces of their own ethnic group compared to faces of another ethnicity (for a review, see Meissner & Brigham, 2001). Although these difficulties with other-race face recognition can pose substantial challenges for applied contexts, such as passport control and eyewitness testimony, the exact mechanisms underlying the ORB remain an issue of active debate. Particularly relevant for the present study, it has been suggested that the ORB results from a lack of motivation to individuate other-race faces and from a failure to attend to individuating information in these faces. Accordingly, an explicit instruction to individuate other-race faces has been reported to reduce or even eliminate the effect (e.g., Hugenberg, Miller, & Claypool, 2007). In the present study, we revisited this idea and examined the extent to which individuating instructions modulate neural correlates of the ORB. Importantly, while previous work has focused exclusively on the effect of individuation instructions on the ORB at recognition, here we were particularly interested in whether such instructions modulate encoding-related neural correlates of own- and other-race face recognition.

Theoretical accounts of the ORB generally fall into one of two categories, those highlighting a lack of perceptual expertise with the other-race category, and those emphasising socio-cognitive or motivational aspects. Perceptual expertise accounts assume that face recognition is finely tuned to the faces in our environment, which happen to be own-race faces for the majority of people. For instance, other-race faces may be processed less efficiently in a configural or holistic manner because most people have only limited experience with them (Hancock & Rhodes, 2008; Tanaka, Kiefer, & Bukach, 2004). In addition, it has been suggested that other-race faces are coded less well along perceptual dimensions in a multidimensional face space (MDFS; Valentine, 1991). These dimensions have been developed to optimally distinguish between the faces we regularly encounter in our environment (i.e., typically own-race faces), but are ill-suited to encode other-race faces (Valentine & Endo, 1992; Valentine, Lewis, & Hills, 2016). Accordingly, deficits during perceptual processing and/or less fine-grained representations of other-race faces are thought to impair subsequent memory for this face category.

Alternatively, socio-cognitive accounts propose an initial categorisation of faces into social in- or out-groups, e.g., in terms of race, when certain out-group defining features, such as skin tone, are detected (e.g., Levin, 1996; 2000). Whereas out-group faces are only processed at a categorical level (Rodin, 1987; Sporer, 2001), in-group faces are processed more in-depth, resulting in superior memory. More recently, Hugenberg and colleagues proposed an integrative account of the ORB, the Categorization – Individuation Model (CIM; Hugenberg, Young, Bernstein, & Sacco, 2010). The CIM postulates that, in addition to social categorisation, perceiver motivation and perceiver experience can modulate the processing of own- and other-race faces. In particular, perceiver motives can redirect attention to individuating information in other-race faces under certain circumstances, for example, when individual identity of other-race faces becomes particularly relevant. Moreover, the perceiver's prior experience with the other-race category can help to individuate other-race faces. However, it is suggested that such expertise can only become effective when the perceiver is sufficiently motivated to individuate other-race faces, and thus expertise arguably plays a less prominent role in this model relative to motivation. Therefore, while previous socio-cognitive accounts are mainly centred around a social categorisation of faces into in- and out-groups, the CIM extends these models by assuming that the initial categorisation can be modulated by situational motives or cues and, at least to some extent, perceptual expertise.

One of the findings often taken to support this account is that the ORB can be reduced or even eliminated when participants are informed about the effect prior to the experiment and are asked to focus on individuating information in other-race faces (Hugenberg et al., 2007; Rhodes, Locke, Ewing, & Evangelista, 2009; Young, Bernstein, & Hugenberg, 2010). These findings suggest that people are in principle able to recognise other-race faces similarly well as own-race faces, but per default do not process them in sufficient detail, unless instructed to do so (Hugenberg et al., 2010). At some variance with these initial findings, others have found these instruction effects to depend on expertise (Pica, Warren, Ross, & Kehn, 2015; Young & Hugenberg, 2012). In these studies, after receiving individuating instructions, participants with higher amounts of other-race contact showed a stronger decrease in the ORB compared to people with more limited other-race contact.

In addition, more recent work has failed to show instruction effects altogether (Wan, Crookes, Reynolds, Irons, & McKone, 2015). Importantly, although participants in this study reported having put more effort into individuating other-race relative to own-race faces, this increased effort did not translate into better memory for other-race faces. Similarly, Crookes and Rhodes (2017) showed that participants spent more time studying other- than own-race faces during a self-paced learning phase. However, this increased effort again did not reduce the ORB (see also Tullis, Benjamin, & Liu, 2014). These latter results are hard to reconcile with socio-cognitive accounts of the ORB and more in line with a perceptual expertise account, as they suggest that increasing motivation is not sufficient to compensate for a lack of long-term experience with other-race faces. To summarise, the findings available at present are quite mixed and show inconsistent effects of individuation instructions on the ORB in recognition memory.

As outlined in the previous paragraphs, the ORB may be modulated by a number of different cognitive and motivational processes, and behavioural measures of memory performance can only directly inform about their combined outcome. By contrast, event-related brain potentials (ERPs) can offer a more fine-grained analysis of the various subprocesses involved in stimulus processing and memory encoding. ERPs reflect transient voltage changes in the encephalogram (EEG) that are time-locked to a specific event, such as the presentation of a visual stimulus. ERPs consist of positive and negative deflections, and these so-called components are associated with distinct subprocesses involved in the perceptual processing and encoding of faces into memory.

In the present study, we were particularly interested in the neural mechanisms underlying successful face learning. To this end, we analysed ERP Dm effects (e.g., Friedman & Johnson, 2000; Paller, Kutas, & Mayes, 1987), which contrast brain activity recorded during the learning phase of a recognition memory experiment for items that are subsequently remembered with items that are subsequently forgotten (see also Figure 1.3 in Chapter 1). Items that are later correctly remembered (subsequent hits) typically elicit more positive amplitudes than subsequent misses over centro-parietal regions starting approximately 300 ms after stimulus onset, and the magnitude of this effect has been found to predict subsequent memory performance (Paller et al., 1987). While this effect was originally reported for words

(Paller et al., 1987), it has also been observed for faces (Sommer, Heinz, Leuthold, Matt, & Schweinberger, 1995; Sommer, Komoss, & Schweinberger, 1997; Sommer, Schweinberger, & Matt, 1991; Yovel & Paller, 2004).

To date, only very few studies have investigated differences in ERP Dm effects for own- and other-race faces. Lucas, Chiao, and Paller (2011) observed more pronounced ERP Dm effects for own- than for other-race faces, which they interpreted to reflect more elaborate processing of own-race faces. Other studies focused on the different contributions of familiarity and recollection (for a review, see Yonelinas, 2002) to own- and other-race face recognition (e.g., Herzmann, Minor, & Adkins, 2017; Herzmann, Minor, & Curran, 2018; Herzmann, Willenbockel, Tanaka, & Curran, 2011). Overall, these studies suggest that successful memory encoding is more effortful for other- compared to own-race faces. For example, Herzmann et al. (2011) found recollection-related ERP Dm effects during encoding to be more pronounced for other- relative to own-race faces, which they interpreted to reflect that, compared to other-race faces, own-race faces are encoded more efficiently and require less neural activation (see also Herzmann et al., 2017). Recent work further showed that ERP Dm effects are sensitive to task difficulty (Herzmann et al., 2018). The authors observed overall more positive amplitudes during a divided attention compared to a focused attention task during encoding, suggesting the recruitment of additional neural resources when the task is more difficult. This modulation of general task difficulty did not differentially affect the behavioural and neural correlates of the ORB, which was interpreted to reflect that differences in own- and other-race face processing were unaffected by an attentional manipulation. However, this study suggests that, in general, ERP Dm effects are susceptible to task difficulty and manipulations of attention.

The aim of the present study was to investigate the effect of individuating instructions on the ORB in recognition memory and encoding-related ERPs. Therefore, participants were randomly assigned to one of two groups (no instruction, instruction). Participants in the instruction group were informed about the ORB and told to pay particular attention to other-race faces during encoding, while participants in the no instruction group did not receive this information. Participants then completed an old/new recognition memory experiment in which they had to learn and remember own- and other-race faces. If the ORB at least partly resulted from a lack of motivation to attend to individual identity in other-race faces (e.g., Hugenberg et al., 2007, 2010), we would expect to find reduced or even no memory advantages for own-race faces in the instruction relative to the no instruction condition. If, however, the ORB exclusively resulted from differences in perceptual expertise, individuating instructions should have little or no effect on the ORB (e.g., Wan et al., 2015). To more directly investigate the mechanisms underlying successful encoding, we compared ERP Dm effects for own- and other-race faces in both groups. Previous research has suggested that these effects reflect the amount of effort put into individuating items during learning (e.g., Herzmann et al., 2011; 2017). Moreover, ERP Dm effects are known to be sensitive to task difficulty (Herzmann et al., 2018). Therefore, if successful learning of other-race faces as a consequence of enhanced motivation also required additional effort, we would expect more pronounced ERP Dm effects for other-race faces in the instruction relative to the no instruction condition.

3.2 Method

3.2.1 Participants

36 participants (26 female, 18 – 36 years, M_{age} = 21.7, SD_{age} = 4.1) with a Caucasian ethnic background took part in the study. None of them reported having lived in a country where the predominant race is East Asian. All participants had normal or corrected-to-normal vision and were right-handed according to the Edinburgh Handedness Questionnaire (Oldfield, 1971). In addition, none of the participants reported to suffer from any skin or neurological conditions or taking any psychoactive medication. Participants gave written informed consent and received £15 or course credit for participating. The study was approved by the Department of Psychology's ethics committee at Durham University.

3.2.2 Stimuli and Apparatus

A total of 384 photographs of unfamiliar faces were used as stimuli. Photographs depicted full frontal views of faces with neutral expression and were taken from various face databases (for origin of images and details regarding ratings of ethnic typicality, see Wiese, Kaufmann, & Schweinberger, 2014). Half of the photographs were of Caucasian faces, the other half showed East Asian faces (50% female, respectively). Using Adobe Photoshop (CS4 Extended, 11.0.2), faces were cut out to remove any extraneous information (e.g., clothing, background), pasted to a uniform black background and converted to greyscale. Stimuli were framed within an area of 170 x 216 pixels (10.55 x 13.41 cm), resulting in a visual angle of 6.7° x 8.5° at a viewing distance of 100 cm. All stimuli were presented on black background in the centre of a computer monitor with a screen resolution of 1024 x 768 pixels. The experiment was created and run using E-Prime software (2.0).

After the experiment, participants completed two questionnaires. The first questionnaire (Hancock & Rhodes, 2008) assessed contact towards Caucasian and Chinese individuals, and participants were required to answer 15 items (e.g., "I interact with Caucasian/Chinese people on a daily basis", "I know lots of Caucasian/Chinese people") on a 6-point scale ranging from "very strongly disagree" to "very strongly agree". The second questionnaire comprised a self-report rating of effort to individuate the faces seen during the experiment (Wan et al., 2015). This questionnaire contained two items where participants had to indicate how much special effort they put into telling apart the faces of Caucasian and Chinese people on a 7-point scale with endpoints labelled as "just normal effort, nothing special" and "a lot of special effort".

3.2.3 Design

Participants were randomly assigned to one of two experimental conditions. Following the procedure adopted by Hugenberg et al. (2007), all participants were told that they would take part in a face recognition experiment consisting of six learning and test phases. They were asked to closely attend to the faces presented during the learning phase as they would be asked to later recognise them. Participants in the instruction condition additionally received instructions aimed at eliciting individuation of other-race faces. They were informed about the own-race bias and instructed to put extra effort into learning other-race faces and pay close attention to individual characteristics in them. Note that we utilised the original instructions employed by Hugenberg et al. (2007) with minor adaptations resulting from the specific own- and other-race categories used in the current experiment (i.e., the ethnic categories “Caucasian” and “East Asian” instead of “White” and “Black”).

3.2.4 Procedure

After providing written consent, participants were prepared for EEG recording and seated in an electrically shielded and sound attenuated chamber. To minimise head movement and to maintain a constant viewing distance, participants were required to put their head in a chin rest. Distance between eyes and computer monitor was approximately 100 cm.

The study comprised six blocks, each consisting of a learning and test phase and with self-paced breaks between blocks. Each learning phase consisted of 32 trials. Within each learning phase, an equal number of Caucasian and East Asian faces was shown (50% female, respectively). All trials were presented in random order. Each trial began with the presentation of a fixation cross presented for 1,000 ms on average (jittered between 750 and 1,250 ms), which was replaced by the face stimulus shown for 3,000 ms. During each test phase, all items presented during the learning phase along with an equivalent number of new items (again, 50% Caucasian, 50% female) were shown, resulting in a total of 64 trials for each test phase. Trials started with the presentation of a fixation cross (again, 1,000 ms on average, jittered between 750 and 1,250 ms). The subsequent face image remained on the screen for 2,000 ms during which participants were required to make old/new judgements via key presses (left and right index finger). Stimuli were presented in random order. Assignment of key presses and the assignment of stimuli to first appear in the learning or test phase were counterbalanced across participants.

3.2.5 EEG recording and data analysis

EEG was recorded from 64 sintered Ag/Ag-Cl electrodes with an ANT Neuro system (Enschede, Netherlands). An electrode on the forehead served as ground and Cz as recording reference. EEG was recorded with a sampling rate of 512 Hz (DC to 120 Hz) with electrode sites corresponding to an extended 10 – 20 system. Correction of blink artefacts was carried out using the algorithm implemented in BESA 6.3 (Gräfelfing, Germany). For analysis of ERP Dm effects, each learning task trial of each participant was manually sorted into “subsequent hits” or “subsequent misses” based on the participant’s response at test. EEG was then segmented from -200 until 1,000 ms relative to stimulus onset. The first 200 ms served as baseline. Artefact rejection was performed using an amplitude threshold of 100 µV and a gradient criterion of 75 µV. All remaining trials were recalculated to average reference, digitally low-pass filtered at 40 Hz (12 dB/oct, zero phase shift) and then averaged according to experimental conditions. The average number of trials was 58.0 (*SD* = 9.0) for subsequent hits and 30.3 (*SD* = 10.3) for subsequent misses for own-race faces and 49.9 (*SD* = 12.6) for subsequent hits and 37.7 (*SD* = 13.4) for subsequent misses for other-race faces in the no instruction group, and 57.2 (*SD* = 11.9) for subsequent hits and 31.7 (*SD* = 9.9) for subsequent misses for own-race faces and 55.3 (*SD* = 11.3) and 33.5 (*SD* = 7.6) for subsequent misses for other-race faces in the instruction group. All participants had more than 16 artefact-free trials in each experimental condition.

In the averaged waveforms, ERP Dm effects were calculated by subtracting subsequent misses from subsequent hits. Next, mean amplitudes were derived from the resulting difference waves for an early (300 – 600 ms) and late (600 – 1,000 ms) time window at electrodes F3, F1, Fz, F2, F4; FC3, FC1, FCz, FC2, FC4, C3, C1, Cz, C2, C4, CP3, CP1, CPz, CP2, CP4, P3, P1, Pz, P2, and P4. Time windows were selected based on visual inspection of the grand averages, but corresponded to those used in previous studies (Herzmann et al., 2011).

Statistical analyses were performed using mixed-model analyses of variance (ANOVA). Following signal detection theory (see, e.g., Wickens, 2002), we analysed the sensitivity measure *d*' (z-standardised hits minus z-standardised false alarm rates) and criterion measure *c* (negative sum of z-standardised his and z-standardised false alarms, divided by 2) in addition to hits and correct rejection (CR) rates. Statistical analyses of self-reported own- and other-race contact and effort to individuate own- and other-race faces, as well as recognition memory performance were performed using mixed-model ANOVAs using the within-subjects factor contact/face ethnicity (own-race, other-race) and the between-subjects factor participant group (instruction, no instruction). Pairwise comparisons were performed using paired samples t-tests. Statistical analyses of ERP Dm effects were carried out using mixed-model analyses of variance (ANOVA) with the within-subjects factors face ethnicity (own-race, other-race), laterality (five factor levels; left, mid-left, midline, mid-right, right) and anterior/posterior (five factor levels; frontal, fronto-central, central, centro-parietal, parietal), as well as the between-subjects factor participant group (instruction, no instruction). When appropriate, degrees of freedom were adjusted according to the Greenhouse-Geisser procedure.

Following an estimation approach in data analysis (see e.g., Cumming, 2012; Cumming & Calin-Jageman, 2017), effect sizes and appropriately sized confidence intervals (CI) are reported throughout. As suggested by Cumming (2012), Cohen's *d* for paired samples t-tests was bias-corrected by using the mean SD rather than the SD of the difference as the denominator (Cohen's d_{unb}) using ESCI (Cumming &

Calin-Jageman, 2017). 90% CIs for partial eta squared (η_p^2) were calculated using scripts provided by M.J. Smithson (http://www.michaelsmithson.online/stats/CIstuff/CI.html).

3.3 Results

3.3.1 Behavioural results

Rating of own- and other-race contact

A mixed-model ANOVA with the within-subjects factor contact ethnicity (own-race, other-race) and the between-subjects factor participant group (instruction, no instruction) revealed that contact with own- and other-race people did not differ between the instruction and no instruction group, $F(1,34) = 0.09$, $p = .769$, $\eta_p^2 = .003$, 90% CI [.00, .08]. A paired-samples t-test on the combined data from both groups revealed that participants reported higher contact with own- ($M = 5.397$, 95% CI [5.09, 5.70]) when compared to other-race people ($M = 2.472$, 95% CI [2.17, 2.78]), $t(35) = 11.17$, $p < .001$, $M_{diff} = 2.925$, 95% CI [2.41, 3.44], $d_{unb} = 3.168$, 95% CI [2.30, 4.16].

Rating of effort

A mixed-model ANOVA on self-report ratings of effort with the within-subjects factor face ethnicity (own-race, other-race) and the between-subjects factor participant group (instruction, no instruction) yielded a significant main effect of ethnicity, $F(1,34) = 18.86$, $p < .001$, $\eta_p^2 = .357$, 90% CI [.14, .51], indicative of more effort put into individuating other- ($M = 4.972$, 95% CI [4.55, 5.40]) compared to own-race faces (*M* = 3.722, 95% CI [3.16, 4.52]). Neither the main effect participant group, $F(1,34) = 0.58$, $p = .451$, $\eta_p^2 = .017$, 90% CI [.00, .14], nor the face ethnicity x participant group interaction, $F(1,34) = 1.13$, $p = .296$, $\eta_p^2 = .032$, 90% CI [.00, .17], reached significance.

Sensitivity d'

A mixed-model ANOVA with the within-subjects factor face ethnicity (own-race, other-race) and the between-subjects factor participant group (instruction, no instruction) on *d*' (Figure 3.1a) yielded a significant main effect of face ethnicity, $F(1,34) = 146.28$, $p < .001$, $\eta_p^2 = .811$, 90% CI [.70, .86], indicating higher sensitivity to own- (*M* = 1.402, 95% CI [1.25, 1.55]) relative to other-race faces (*M* = 0.837, 95% CI [0.68, 1.00]), $M_{diff} = 0.565$, 95% CI [0.47, 0.66], $d_{unb} = 1.739$, 95% CI [1.15, 2.48]. The main effect of participant group did not reach statistical significance, $F(1,34) = 0.78$, $p = .383$, $\eta_p^2 = .022$, 90% CI [.00, .15]. Interestingly, the face ethnicity x participant group interaction approached significance, $F(1,34) = 4.04$, $p = .052$, $\eta_p^2 = .106$, 90% CI [.00, .27]. Additional tests carried out to test the a priori prediction of an absent ORB in the instruction condition revealed significantly higher sensitivities for own- when compared to other-race faces both in the instruction, $t(17) = 7.06$, $p < .001$, $M_{diff} = 0.471$, 95% CI [0.33, 0.61], $d_{unb} = 1.051$, 95% CI [0.62, 1.57], as well as in the no instruction group, $t(17) = 10.07$, $p < .001$, $M_{diff} = 0.659$, 95% CI [0.52, 0.80], $d_{unb} = 1.053$, 95% CI [0.67, 1.52]. The interaction reflects a trend for the ORB to be reduced in the instruction compared to the no instruction group.

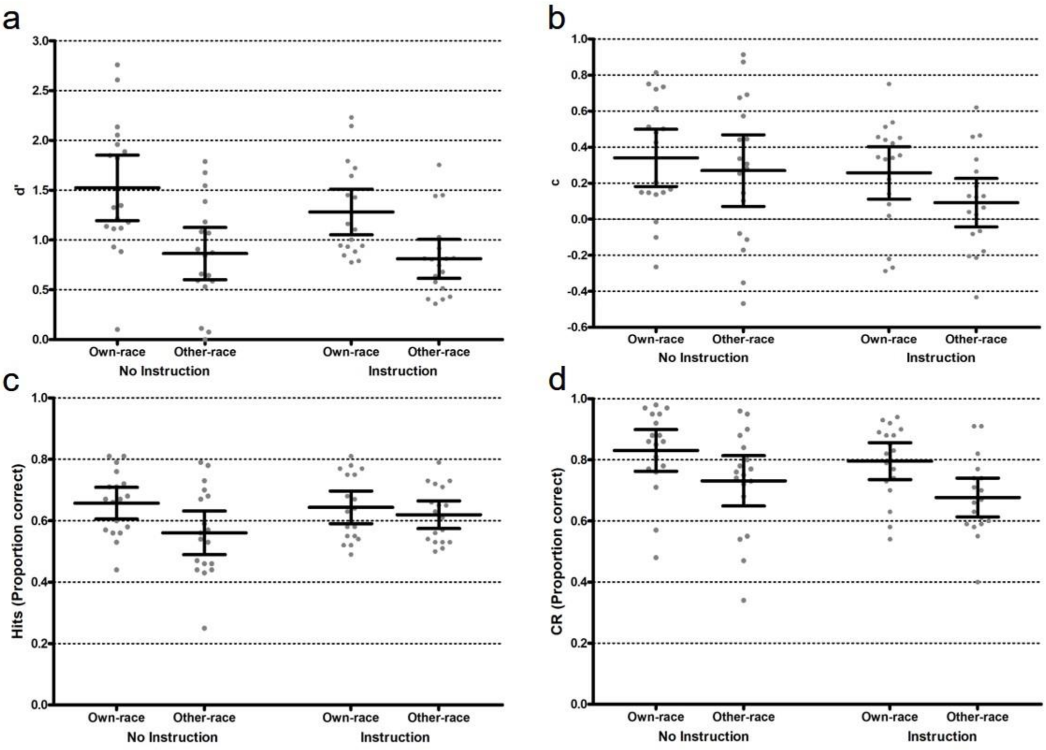

Figure 3.1 Behavioural results. (a) *d*' and (b) *c* as well as (c) hit and (d) correct rejection (CR) rates for own- and other-race faces in the no instruction and instruction group.

Criterion c

A corresponding ANOVA on *c* indicated a significant main effects of face ethnicity, $F(1,34) = 11.65$, $p = .002$, $\eta_p^2 = .255$, 90% CI [.07, .43], with overall more conservative responses to own-race ($M = -0.299$, 95% CI [-0.40, -0.20]) compared to other-race faces ($M = -0.181$, 95% CI [-0.30, -0.07]). Neither the main effect of participant group, $F(1,34) = 1.62$, $p = .211$, $\eta_p^2 = .046$, 90% CI [.00, .19], nor the face ethnicity x participant group interaction, $F(1,34) = 1.86$, $p = .182$, $\eta_p^2 = .052$, 90% CI [.00, .20], reached significance (Figure 3.1b).

Accuracies

A corresponding analysis on hits (Figure 3.1c) revealed significant main effects of face ethnicity, $F(1,34) = 16.43$, $p < .001$, $\eta_p^2 = .326$, 90% CI [.12, .49], which further interacted with participant group, $F(1,34) = 5.99$, $p = .020$, $\eta_p^2 = .150$, 90% CI [.01, .32]. Post-hoc comparisons showed higher hit rates for own-race compared to other-race faces in the no instruction group, $t(17) = 4.32$, $p < .001$, $M_{\text{diff}} = 0.097$, 95% CI [0.05, 0.14], $d_{\text{unb}} = 0.738$, 95% CI [0.33, 1.20]. No comparable difference was detected in the instruction group, $t(17) = 1.22$, $p = .240$, $M_{\text{diff}} = 0.024$, 95% CI [-0.02, 0.07], $d_{\text{unb}} = 0.231$, 95% CI [-0.16, 0.64].

For CR (Figure 3.1d), a significant main effect of face ethnicity, $F(1,34) = 79.07$, $p < .001$, $\eta_p^2 = .699$, 90% CI [.53, .78], indicated significantly higher CR rates to own-race ($M = 0.813$, 95% CI [0.78, 0.85]) compared to other-race faces ($M = 0.704$, 95% CI [0.65, 0.76]). Neither the main effect of participant group, $F(1,34) = 1.00$, $p = .324$, $\eta_p^2 = .029$, 90% CI [.00, .16], nor the face ethnicity x participant group interaction, $F(1,34) = 0.63$, $p = .434$, $\eta_p^2 = .018$, 90% CI [.00, .14], reached significance.

3.3.2 ERP results

Grand average ERPs for subsequent hits and subsequent misses for own- and other-race faces are depicted in Figures 3.2 and 3.3. Figure 3.2 shows ERP data from the no instruction group, Figure 3.3 shows ERP data from the instruction group.

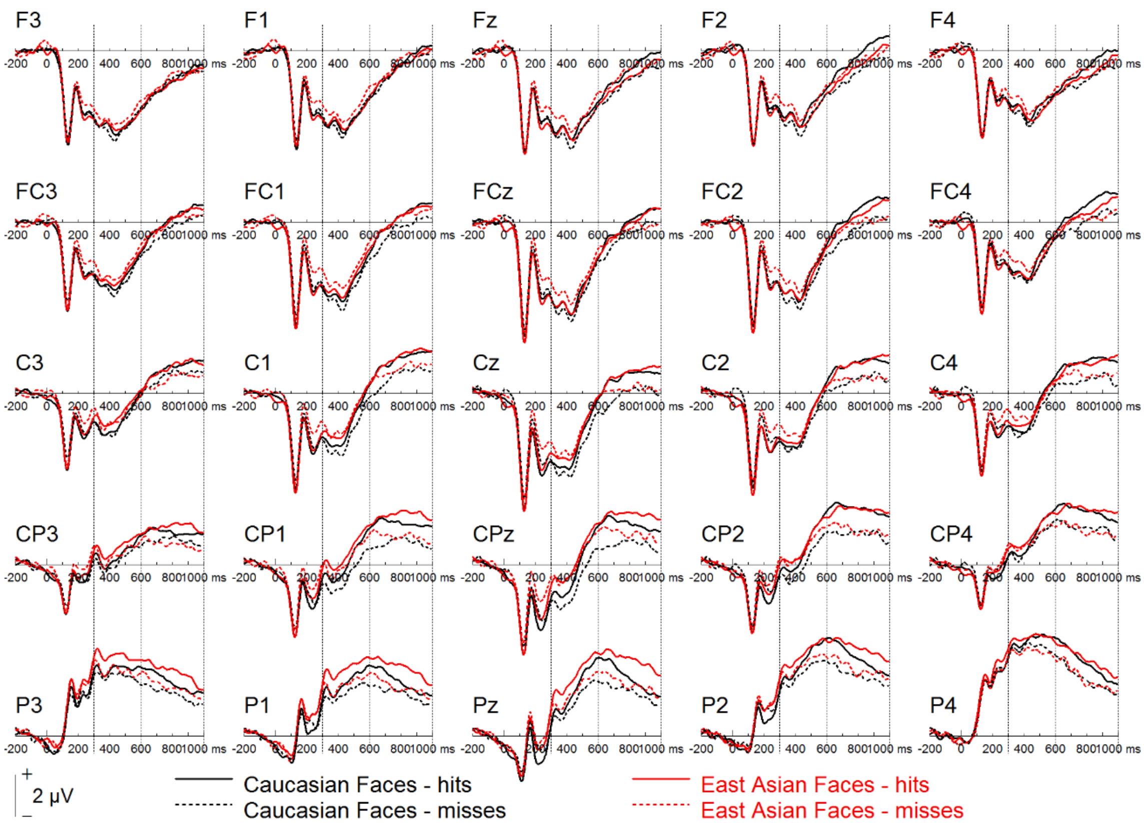

Figure 3.2 Grand average ERPs from the no instruction group. Dotted lines denote time ranges selected for analysis of ERP Dm effects.

Early ERP Dm effect (300 – 600 ms)

A mixed-model ANOVA with the within-subjects factor face ethnicity (own-race, other-race), laterality (left, mid-left, midline, mid-right, right) and anterior/posterior (frontal, fronto-central, central, centro-parietal, parietal) as well as the between-subjects factor participant group (instruction, no instruction) yielded a significant main effect of anterior/posterior, $F(4,136) = 8.12$, $p = .003$, $\eta_p^2 = .193$, 90% CI [0.08, 0.27], reflecting a gradual increase in ERP Dm effects from anterior to posterior sites. Crucially, a significant laterality x face ethnicity x participant group interaction was observed, $F(4,136) = 2.92$, $p = .024$, $\eta_p^2 = .079$, 90% CI [0.01, 0.14]. Post-hoc comparisons to test for potential differences between ERP Dm effects in the no instruction and instruction groups revealed significantly larger ERP Dm effects for other-race faces in the instruction relative to the no instruction group at midline, $F(1,34) = 5.94$, $p = .020$, $\eta_p^2 = .149$, 90% CI [0.01, 0.32], and mid-right hemispheric electrodes, $F(1,34) = 4.81$, $p = .035$, $\eta_p^2 = .124$, 90% CI [0.00, 0.29], all other Fs $\leq$ 2.32, ps $\geq .139$, $\eta_p^2 \geq .137$ (Figure 3.4). Corresponding differences between ERP Dm effects in the instruction and no instruction group were not detected for own-race faces, all Fs ≤ 0.66, ps $\geq .422$, $\eta_p^2 \geq .019$.

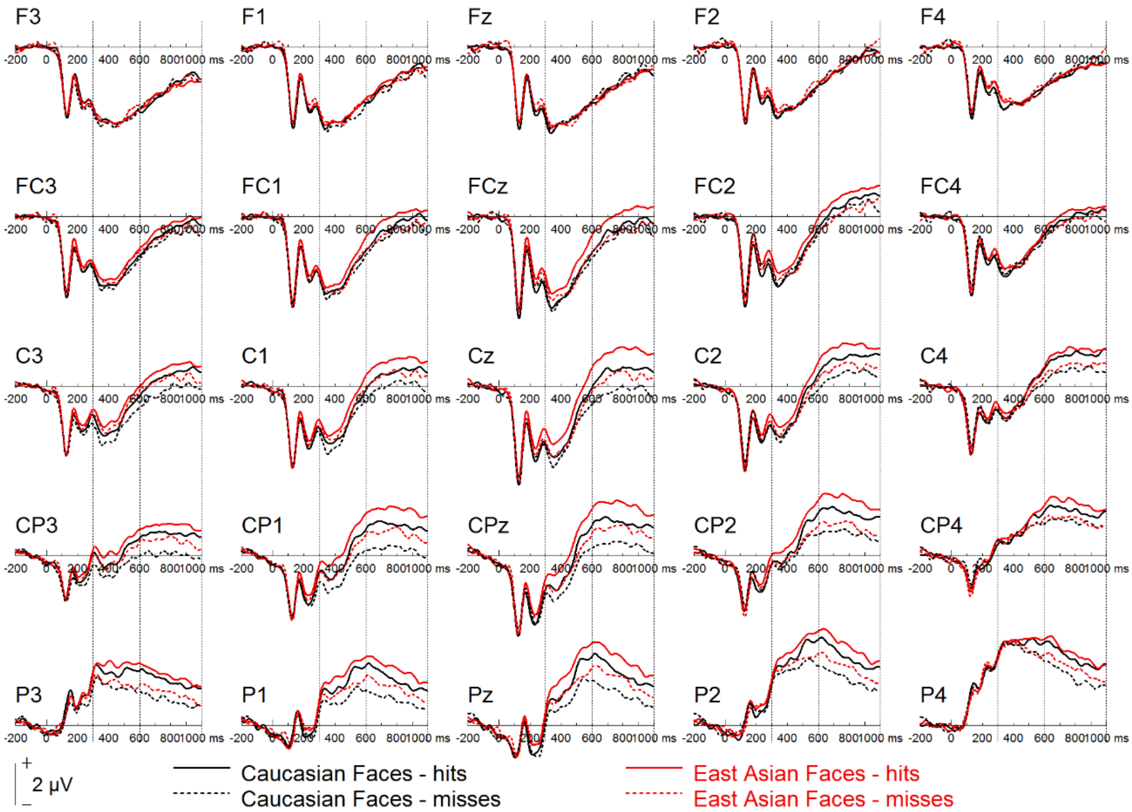

Figure 3.3 Grand average ERPs from the instruction group. Dotted lines denote time ranges selected for analysis of ERP Dm effects.

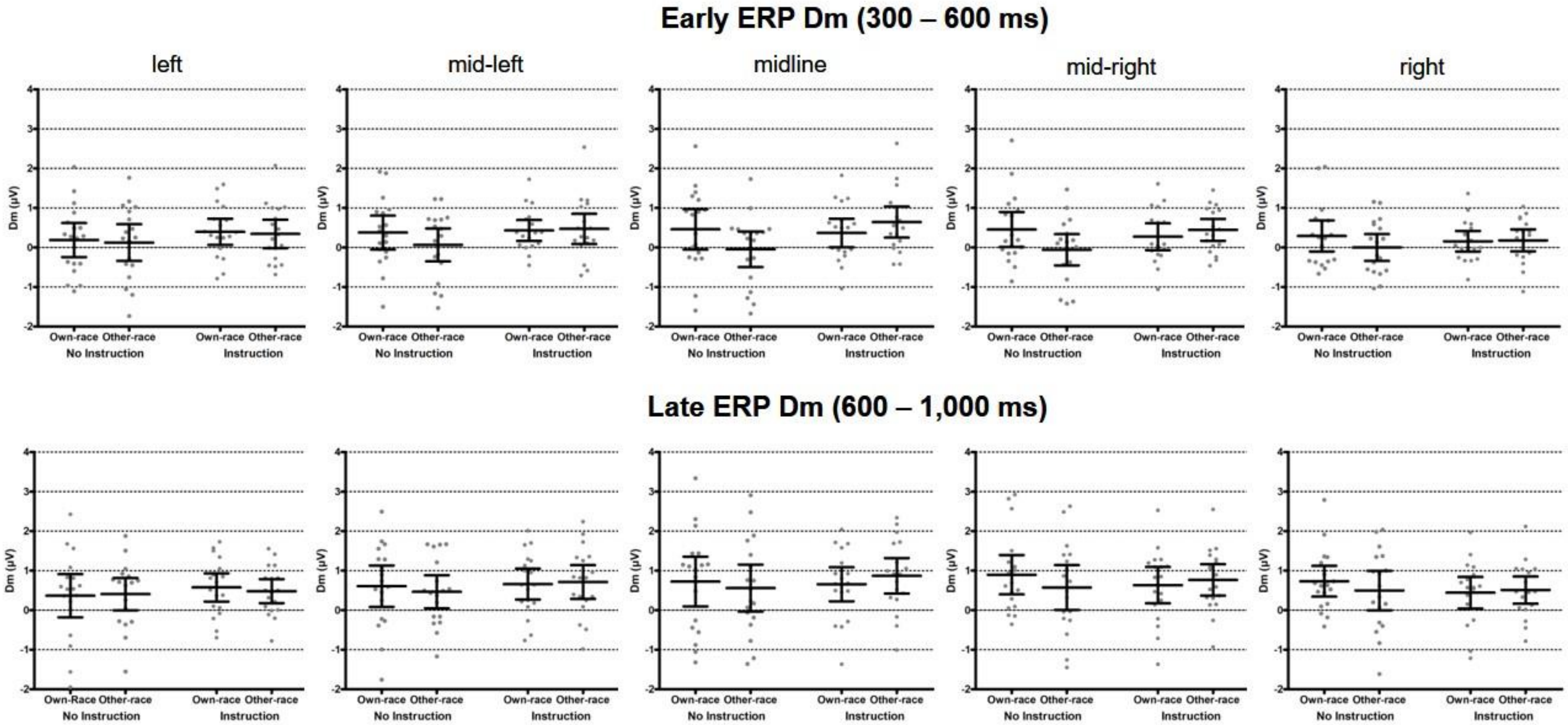

Figure 3.4 ERP Dm effects. Early (top row) and late (bottom row) ERP Dm effects (i.e., the difference in µV between subsequent hits and misses) for own- and other-race faces in the no instruction and instruction group for each of the five levels of laterality.

Late ERP Dm effect (600 – 1,000 ms)

A corresponding mixed-model ANOVA on the late ERP Dm time window again revealed a significant main effect of anterior/posterior, $F(4,136) = 12.51$, $p < .001$, $\eta_p^2 = .269$, 90% CI [0.15, 0.35], reflecting more pronounced ERP Dm effects over posterior relative to anterior sites. No other significant effects were observed, all $F\text{s} \leq 2.12$, $p\text{s} \geq .081$, $\eta_p^2 \geq .059$.

3.4 Discussion

The aim of the present study was to investigate the effect of individuating instructions on behavioural and encoding-related neural measures of the ORB. We therefore compared a group of participants who received explicit instructions to closely attend to other-race faces during learning prior to the experiment with a control group that did not receive comparable instructions. In line with socio-cognitive accounts, individuating instructions reduced the ORB in recognition memory relative to the no instruction condition. Moreover, more pronounced early ERP Dm effects for other-race faces were found in the instruction relative to the no instruction group, which may suggest that individuating instructions encouraged more effortful processing of other-race faces. These findings are discussed in more detail below.

In line with previous work (Hugenberg et al., 2007; Rhodes et al., 2009; Young et al., 2010), the ORB in recognition memory was attenuated for participants in the instruction group. This was clearly evident in hit rates, which revealed a significant ORB in the no instruction but not in the instruction group. Moreover, as evident from Figure 3.1 c, the absence of a significant effect in the latter group resulted from improved recognition of other-race faces. A trend towards a reduced

ORB in the instruction condition was also observed in *d*'. However, the ORB was still significant in both groups. Thus, in the present study, individuating instructions most directly affected participants' 'old' responses to other-race faces, without a comparable benefit in sensitivity (or correct rejection rates). It thus appears possible that this increase in hit rates for other-race faces was at least partly based on a change in criterion between the groups. However, our analysis of the response criterion did not reveal a corresponding significant effect. Accordingly, our findings appear to be best interpreted as reflecting an increase in performance for other-race faces in the instruction group, which is selective for those items that were presented during learning.

Surprisingly, although individuating instructions improved hit rates for other-race faces, participants in this group did not report having put more effort into individuating other-race faces than participants in the no instruction group. Indeed, all participants reported more effort for other- relative to own-race faces, irrespective of group. While the reason for this result is somewhat unclear, it may partly reflect a general insensitivity of this measure that is based on subjective self-report. Interestingly, however, our results are in line with Wan et al. (2015) who also observed more self-reported effort allocated to other- relative to own-race faces, even when participants are not explicitly instructed to do so.

The finding of increased hit rates for other-race faces in the individuating instruction condition was paralleled by our ERP results. More specifically, between 300 and 600 ms, other-race faces elicited significantly larger ERP Dm effects in the instruction relative to the no instruction group. It has previously been suggested that increased amplitudes for successfully remembered other-race faces in ERP Dm effects reflect more effortful encoding (e.g., Herzmann et al., 2011). Thus, in the present study individuating instructions may have encouraged participants to allocate more attentional resources to other-race faces during encoding, which, as discussed above, reduced the ORB in recognition memory. In contrast, ERP Dm effects for own-race faces did not differ between groups, which might indicate that, as intended, instructions specifically encouraged more effortful processing of other-race faces.

ERP Dm effects in the present study reflect differences between subsequent hits and misses, while Herzmann and colleagues (2011; 2017; 2018) analysed differences between recollection- and familiarity-based recognition during encoding, which makes a direct comparison of our results with those from previous studies somewhat difficult (see also Herzmann et al., 2011). However, more pronounced ERP Dm effects for other-race faces as observed in the present study may nonetheless suggest that successful recognition is more effortful for other- relative to own-race faces (Herzmann et al., 2011; 2017), irrespective of whether these effects reflect recollection- or familiarity-based recognition. Of note, the only other study that examined ERP Dm effects for subsequent hits and misses found more pronounced effects for own- relative to other-race faces (Lucas et al., 2011). In the present study, however, ERP Dm effects for own- and other-race faces did not differ significantly in the no instruction condition. While the reason for these discrepant findings is not entirely clear, it might be related to differences in experimental design. In particular, Lucas et al. (2011) presented faces from different ethnic categories in separate blocks, which may have resulted in less effortful processing of other-race faces, as such designs are presumably particularly sensitive to reducing attention or motivation to individuate.

In the present study, a modulation of ERP Dm effects by experimental factors was observed in an early (300 – 600 ms) but not in a later (600 – 1,000 ms) time window. Previous studies mostly revealed a somewhat later onset of ERP Dm effects (Herzmann et al., 2018; but see Sommer et al., 1991). While some general discrepancies between studies with respect to the temporal characteristics of ERP Dm effects are not surprising, the comparatively early onset of differential effects in the present study might reflect that individuating instructions modulated relatively early perceptual and/or attentional processes during memory encoding. In addition, although more pronounced ERP Dm effects were observed at posterior relative to frontal sites, experimental factors did not further interact with anterior or posterior electrode positions, suggesting that individuating instructions led to widespread modulations over centro-parietal regions. Of note, our analyses indicated that the difference in ERP Dm effects for other-race faces between groups was most prominent at midline and right-lateralised sites (Figure 3.4).

As discussed above, the findings that individuating instructions eliminated the ORB in hit rates fits well with a socio-cognitive account of the ORB (Hugenberg et al., 2007; 2010). At the same time, a clear ORB was observed in both groups for *d*'. These results suggest that the ORB may partly reflect the failure to attend to other-race faces during encoding, which can to some extent be compensated by explicitly instructing participants to attend to other-race faces prior to the experiment. Yet, as suggested by the finding of more pronounced ERP Dm effects for other-race faces in the instruction relative to the no instruction group, this increase in other-race face recognition required more effortful processing during learning. The finding of a clear memory advantage for own-race faces in *d*' - even though participants preferentially allocated their attentional resources to other-race faces during learning - suggests that other factors, such as reduced expertise with the other-race category, likely contributed substantially to the ORB in the present study.

In conclusion, individuating instructions attenuated the ORB in recognition memory and increased ERP Dm effects for other-race faces. These results support previous suggestions that high levels of attention and increased effort put into individuating other-race faces during encoding can reduce the ORB. However, such additional effort appears to come with costs, which is indicated by enhanced neural processing. Moreover, the finding of a clear ORB in sensitivity even in the instruction group suggests that other factors such as reduced experience with other-race faces play an important role in the generation of the effect.

4 Learning own- and other-race facial identities from natural variability

Exposure to multiple varying face images of the same person encourages the formation of identity representations which are sufficiently robust to allow subsequent recognition from new, never-before seen images. While recent studies suggest that identity information is initially harder to perceive in images of other- relative to own-race identities, it remains unclear whether these difficulties propagate to face learning, i.e., to the formation of robust face representations. We report two experiments in which Caucasian and East Asian participants sorted multiple images of own- and other-race persons according to identity in an implicit learning task and subsequently either matched novel images of learnt and previously unseen faces for identity (Experiment 1) or made old/new decisions for new images of learnt and unfamiliar identities (Experiment 2). Caucasian participants demonstrated own-race advantages during sorting, matching and old/new recognition while corresponding effects were absent in East Asian participants with substantial other-race expertise. These participants sorted own- and other-race faces equally well and even showed enhanced learning for other-race identities during matching in Experiment 1. This result likely reflects increased motivation to individuate other-race faces, which lends further support to recent suggestions on how perceptual expertise and socio-cognitive factors interact during the processing of own- and other-race faces.

4.1 Introduction

We are able to identify a familiar face from almost any photograph, and this remarkable ability holds even when never-before seen and poor-quality images are used (Burton, Wilson, Cowan, & Bruce, 1999). This has led to the widely held belief that we are "face experts". However, this expertise for faces appears to be far more confined than initially thought, and is, in effect, limited to familiar faces (Young & Burton, 2018). Previous research has shown that we have substantial difficulty recognising unfamiliar faces (Bruce et al., 1999), which appears to be even more pronounced if these faces are from a different ethnic group (Meissner & Brigham, 2001). The difference between familiar and unfamiliar face recognition, and the process that transfers unfamiliar into familiar faces, i.e., face learning, are widely researched, but not yet completely understood. Given the well-documented difficulty in unfamiliar other-race face recognition, the present study investigated whether it is also more difficult to learn other-race facial identities.

Previous studies have shown that unfamiliar face recognition is highly image-dependent and substantially impaired by changes in e.g., viewpoint or expression (e.g., Hancock, Bruce, & Burton, 2000; Longmore, Liu, & Young, 2008). For example, participants make approximately 30% errors when identifying a target face from a different picture in a simultaneously presented array of 10 faces, despite the fact that all photographs depict frontal views and are taken on the same day (e.g., Bruce et al., 1999; Megreya & Burton, 2007). Error rates remain high in matching tasks even when only two different face photographs are presented side-by-side and participants have to decide whether these show the same or different persons (e.g., Burton, White, & McNeill, 2010). Of particular relevance, Jenkins and colleagues presented participants with 20 "ambient" images (i.e., photographs taken from the internet that vary “naturally” in viewing angle, expression, hairstyle, etc.) of each of two unfamiliar identities and asked them to sort the pictures into as many piles as they perceived identities in the set (Jenkins, White, Van Montfort, & Burton, 2011). Participants considerably overestimated the actual number of identities and sorted the pictures into an average of 7.5 piles. Interestingly, corresponding tasks with images of familiar faces resulted in near-perfect performance.

In addition to these well-documented problems with unfamiliar face recognition, people remember faces from a different ethnic group less accurately than faces from their own ethnicity (Meissner & Brigham, 2001). Attempts to explain this own-race bias (ORB) have focused either on perceptual expertise or socio-cognitive factors. Perceptual expertise accounts assume that reduced contact and lack of experience with other-race faces result in reduced configural and/or holistic processing (Hayward, Crookes, & Rhodes, 2013; Michel, Rossion, Han, Chung, & Caldara, 2006; Rhodes et al., 2009) or less precise memory representations (Valentine & Endo, 1992; Valentine, Lewis, & Hills, 2016), ultimately impairing recognition memory. Alternatively, socio-cognitive accounts suggest that other-race faces are categorised into social out-groups. Consequently, processing is thought to be restricted to category-level information while individuating information is assumed to be derived from own-race faces (Hugenberg, Young, Bernstein, & Sacco, 2010; Levin, 1996). However, it is further suggested that, given sufficient motivation, other-race faces can be individuated. Accordingly, increasing motivation to individuate has been reported to eliminate the ORB (Hugenberg, Miller, & Claypool, 2007).

Although typically demonstrated in recognition memory paradigms, an ORB has also been observed in simultaneous matching tasks, suggesting that the effect is, at least partly, related to perceptual deficits and not entirely memory-based (Megreya, White, & Burton, 2011). This conclusion is also in line with evidence from event-related brain potentials, indicating that difficulties at perceptual processing stages are correlated with the ORB in face memory (Wiese, Kaufmann, & Schweinberger, 2014; Wiese & Schweinberger, 2018). At the same time, researchers have only recently begun to investigate differences in the perception of own- and other-race facial identities using multiple ambient images of the depicted persons (e.g., Laurence, Zhou, & Mondloch, 2016; Yan, Andrews, Jenkins, & Young, 2016; Zhou & Mondloch, 2016). These studies report that, in a sorting task similar to Jenkins et al. (2011), participants typically perceive even more other-race than own-race identities, suggesting that identity information is even harder to extract from unfamiliar other-race faces. As sorting tasks arguably encourage individuation of the identities at hand (for a related discussion, see Hayward, Favelle, Oxner, Chu, & Lam, 2017), these findings support an expertise-based account of the ORB and extend difficulties with other-race faces to the recognition of facial identity.

Interestingly, sorting tasks can also be employed for face identity learning. When participants are informed about the correct number of identities in the set subsequent performance for these faces improves substantially (Andrews, Jenkins, Cursiter, & Burton, 2015). Specifically, in a subsequent matching task, previously unseen images of identities seen during sorting are matched more accurately than images of new identities. This suggests that exposure to within-person variability during sorting encourages the formation of so-called robust representations that enable recognition of the face independent of a specific image (Andrews, Burton, Schweinberger, & Wiese, 2017; Andrews et al., 2015; Burton, Kramer, Ritchie, & Jenkins, 2016).

Recently, Matthews and Mondloch (2018) also observed a benefit of exposure to multiple images for other-race identity learning. After extensive training, novel exemplars of the learnt other-race identities were matched more accurately than images of unfamiliar other-race identities. To date, however, only very few studies have directly compared own- and other-race face learning, and have not provided consistent findings. Cavazos and colleagues showed similar benefits of multi-image learning on own- and other-race face recognition although an ORB in recognition memory was still evident (Cavazos, Noyes, & O'Toole, 2018). At variance with this finding, Hayward et al. (2017) provided evidence that it is more challenging to learn other-race as compared to own-race identities from varying images. In this study, a name identification test with new images of the learnt identities revealed higher accuracies for identifying own-race compared to other-race identities. Similarly, Zhou, Matthews, Baker, and Mondloch (2018) showed an own-race advantage in a paradigm where identities were learnt from a single image, a low variability video, or a high variability video. The authors found that, relative to own-race faces, exposure to a higher degree of within-person variability was needed during other-race face learning to subsequently recognise the faces from novel images. Together, the majorities of these studies provide some initial support for an increased challenge to incorporate novel exemplars into newly formed other-race face representations.

In sum, previous work has shown difficulties to cohere ambient images of unfamiliar faces into distinct identity representations (Jenkins et al., 2011) which are even more pronounced for other-race faces (Laurence et al., 2016). Although sorting of unfamiliar own-race identities has been shown to result in incidental learning (Andrews et al., 2015), no study investigating differences in the perception of own-and other-race identities from ambient images has yet addressed whether difficulties during sorting propagate to subsequent matching and recognition of novel exemplars of the learnt identities. This question is arguably of particular relevance, given that in daily life people presumably learn new facial identities from exposure to variability. Moreover, as noted above, the paradigms and findings of previous studies on own- and other-race face identity learning are somewhat mixed. While Cavazos et al. (2018) found that own- and other-race identification benefits similarly from exposure to variability during learning, others found an advantage for own-race identity learning (Hayward et al., 2017; Zhou et al., 2018). Of note, Cavazos et al. (2018) used a relatively limited number of images with restricted variability. Moreover, Hayward et al. (2017) used a naming task. Accordingly, any reduced performance for other-race faces could in principle result from increased difficulty of accessing new name-face associations rather than from face recognition per se. Put differently, it is possible in such tasks that participants recognise the face, but do not remember the correct name.

Here, we report two experiments investigating own- and other-race identity learning. In both experiments, Caucasian and East Asian participants sorted own- and other-race faces according to identity in separate blocks. To promote learning, participants were informed that only two identities were present. Following each sorting task, they engaged in a matching task (Experiment 1) or an old/new recognition task (Experiment 2) in which previously unseen images of the identities seen during sorting (learnt identities) and of unfamiliar (novel) identities were presented. We expected a differential pattern of results for own- and other-race faces across the sorting and matching/recognition tasks. Given the particular difficulties to extract identity-diagnostic information from other-race faces when presented with ambient images (e.g., Laurence et al., 2016), we expected better performance during sorting for own- relative to other-race identities. We also predicted more difficulties with other-race faces in the subsequent matching and old/new recognition tasks. In Experiment 1, we expected a general benefit of prior familiarisation with the identities (Andrews et al., 2015), which would be reflected in better matching for learnt when compared to novel identities. We further hypothesised that previous exposure would be particularly beneficial for own-race identities, resulting in larger learning effects for own- relative to other-race faces. In Experiment 2, a similar learning advantage for own-race identities was expected which would be reflected in more accurate recognition of own- compared to other-race identities. Finally, we note that our East Asian participants were tested while attending a UK university, which likely enabled them to acquire substantial expertise with Caucasian faces. We therefore expected differences between own- and other-race faces to be attenuated in East Asian relative to Caucasian participants.

4.2 Experiment 1

4.2.1 Method

Participants

The sample comprised 24 Caucasian (22 female, 18-42 years, M_{age} = 21.5, SD_{age} = 5.1) and 24 East Asian undergraduate and postgraduate students (21 female, 19-31 years, M_{age} = 21.5, SD_{age} = 2.9) at Durham University. East Asian participants had been living in the UK for 2 to 48 months. All participants gave written informed consent to take part in the study and received course credit or £5. The study was approved by the local ethics committee.

Stimuli and Design

40 images of each of four Caucasian and four East Asian male models unfamiliar to the participants were collected via Google image search (for more detailed information, see Andrews et al. (2017). Rectangles around the face were cut out of the original pictures, re-sized to 190 x 285 pixels, and converted to grey scale. All images were also printed at 3 x 4 cm, laminated and cut out to create stimuli for the sorting task (see below). Following the main experiment, participants were asked to judge the quality of contact with Caucasian and East Asian people on a scale from 1 (very superficial) to 4 (very intense) (Wiese, 2012).

For each identity, images were randomly divided into two sets (A, B) of 20 images each. The identities within each ethnic group were paired (ID1/2, ID3/4), resulting in four different image sets for each ethnic group (A and B for ID1/2 and ID3/4, respectively).

Participants completed a sorting and a matching task, once with Caucasian and once with East Asian identities in separate blocks. The order of blocks (Caucasian first, East Asian first) was counterbalanced across participants. For the sorting task, one of the image sets for the respective ethnic group was used. The identity set presented in the sorting task (ID1/2A, ID1/2B, ID3/4A or ID3/4B) was counterbalanced across participants.

In the subsequent matching task, two face images were presented side-by-side on a computer screen on grey background. 80 trials, i.e., 20 match and 20 mismatch trials each for the learnt identities encountered in the sorting task, and the two previously unseen (novel) identities, were completed. The two images were presented at 7 x 11.2 cm, separated by a 4.3 cm gap. Each image was presented twice, once in a match and once in a mismatch trial. Within the respective categories (match or mismatch trials for learnt or novel identities, respectively), the two images contributing to each stimulus pair were selected randomly. All presented images of learnt identities were novel exemplars to test for identity learning independent of a specific image set (e.g., if participants sorted set 1A, images presented during matching were those of set 1B).

Procedure

After providing consent, participants completed the first sorting task. They received a pile of shuffled cards and were informed that the cards depicted two different persons with 20 images per identity. They were asked to sort the images into two clusters, one for each identity, without time restriction. They were told to arrange images of the same person next to one another, so that all images could be seen simultaneously. Participants were then seated in front of a computer monitor to participate in the first matching task. They were told that they would see a pair of face images on the screen and that their task was to judge as accurately as possible whether the two faces presented in each trial depicted the same or two different identities. Images remained on the screen until participants keyed in their response. Finally, participants completed the second sorting and matching task, using stimuli from the ethnic group not used in the first block.

Sorting errors were calculated by determining the number of images of one identity (e.g., ID1) incorrectly sorted into a pile containing a majority of images of the second identity in the set (e.g., ID2). Statistical analyses were performed using mixed-model analyses of variance (ANOVA). Quality of contact (reported in Table

4.1) and sorting task errors were analysed using the within-subjects factor contact/stimulus ethnicity (Caucasian, East Asian) and the between-subjects factor group (Caucasian, East Asian). Analysis of matching task performance involved the additional within-subjects factors familiarity (learnt, novel) and trial type (match, mismatch). Post-hoc comparisons were performed using paired samples t-tests. Additionally, we tested our a priori hypothesis of larger learning effects in the matching task for own- relative to other-race identities with planned contrasts (learnt minus novel for both Caucasian and East Asian identities in Caucasian and East Asian participants, respectively) using t-tests. Following an estimation approach, estimates of effect sizes (Cohen's *d*) and their corresponding 95% confidence intervals (CIs) are reported, which were calculated using ESCI (Cumming & Calin-Jageman, 2017). As suggested by Cumming and Calin-Jageman (2017), Cohen's *d* for paired samples t-tests was corrected for bias and calculated by using the mean SD (and not the SD of the difference) as the denominator (Cohen's d_{unb}).

4.2.2 Results

For the sake of conciseness, we only report those results that directly relate to our hypotheses in the main text. A complete list of all significant effects is presented in Table 4.1.

A mixed-model ANOVA on sorting errors (Figure 4.1A) with the within-subjects factor stimulus ethnicity and the between-subjects factor group revealed a significant interaction, $F(1,46) = 12.75$, $p = .001$, $\eta^2_p = .217$. Post-hoc contrasts conducted for each participant group separately revealed fewer sorting errors for own- relative to other-race identities in Caucasian, $t(23) = 4.03$, $p = .001$, M_{diff} =

2.208, 95% CI [1.07, 3.34], Cohen's d_{unb} = 0.901, 95% CI [0.40, 1.45], but not in East Asian participants, $t(23) = 0.90$, $p = .375$, M_{diff} = -0.458, 95% CI [-1.51, 0.59], Cohen's d_{unb} = -0.207, 95% CI [-0.68, 0.26].

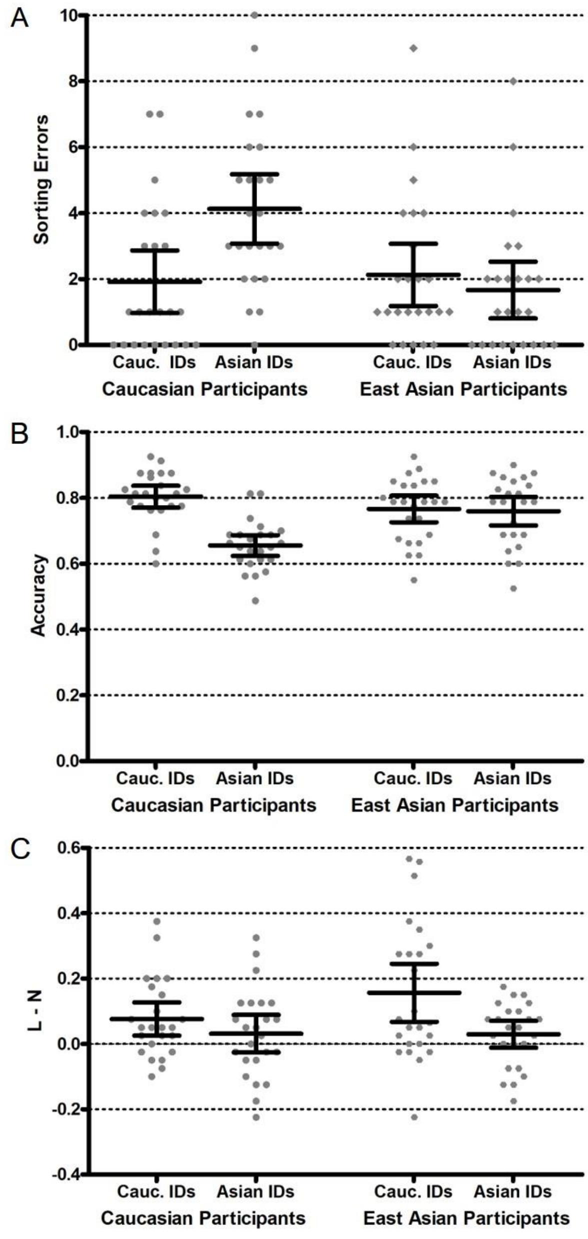

Figure 4.1 Results of Experiment 1. (A) Sorting errors, (B) matching task accuracy and (C) learning effects during matching (difference in accuracy between learnt and novel identities) for Caucasian and East Asian identities in Caucasian and East Asian participants. Error bars denote 95% confidence intervals (CI), grey dots represent individual subject data.

During matching, a mixed-model ANOVA with the within-subjects factors stimulus ethnicity and familiarity as well as the between-subjects factor group yielded a significant main effect of familiarity with overall better performance for learnt relative to novel identities, $F(1,46) = 22.40$, $p < .001$, $\eta^2_p = .327$. Furthermore, a stimulus ethnicity x group interaction was observed (Figure 4.1B), $F(1,46) = 29.00$, $p < .001$, $\eta^2_p = .387$, revealing better matching of own- versus other-race identities in Caucasian, $t(23) = 10.21$, $p < .001$, $M_{diff} = 0.148$, 95% CI [0.12, 0.18], Cohen's d_{unb} = 1.879, 95% CI [1.27, 2.61], and comparable matching of own- and other-race faces in East Asian participants, $t(23) = 0.31$, $p = .760$, $M_{diff} = -0.007$, 95% CI [-0.05, 0.04], Cohen's $d_{unb} = -0.066$, 95% CI [-0.50, 0.37].

Additional analyses to test our a priori hypothesis of more pronounced learning effects (learnt – novel) for own- compared to other-race identities (Figure 4.1C) revealed only numerically larger learning effects for own- relative to other-race identities in Caucasian participants, $t(23) = 1.50$, $p = .148$, $M_{diff} = 0.045$, 95% CI [-0.02, 0.11], Cohen's $d_{unb} = 0.337$, 95% CI [-0.12, 0.81]. Surprisingly, East Asian participants demonstrated significantly larger learning effects for other- than for own-race identities, $t(23) = 2.69$, $p = .013$, $M_{diff} = -0.127$, 95% CI [-0.23, -0.03], Cohen's $d_{unb} = -0.749$, 95% CI [-1.38, -0.16].

The matching task results were additionally confirmed in a by-item analysis. While the stimulus ethnicity x familiarity x group interaction was not significant, $F(1,304) = 0.49$, $p = .484$, $\eta^2_p = .002$, separate one-way ANOVAs comparing learning effects (learnt – novel) for own- and other-race items in Caucasian and East Asian participants respectively, revealed a trend for larger learning effects for own-

Table 4.1 Full list of significant statistical results of Experiment 1.

Analysis	Effect	*df*	*F*	*p*	η^2_p	Post-hoc comparison	*df*	*t*	*p*	M_{diff}	95% CI	d_{unb}	95% CI
Quality of contact	Contact ethnicity					Cauc. participants:							
	x group	1,46	169.60	<.001	.787	Own- vs. other-race	23	*13.16*	<.001	2.083	1.76, 2.41	3.578	2.49, 4.89
						Asian participants:							
						Own- vs. other-race	23	6.99	<.001	1.708	1.20, 2.21	2.289	1.40, 3.30
Sorting task errors	Stimulus ethnicity	1,46	5.49	.024	.107								
	Group	1,46	4.44	.041	.088								
	Stimulus ethnicity					Cauc. participants:							
	x group	1,46	12.75	.001	.217	Own- vs. other-race	23	4.03	.001	2.208	1.07, 3.34	0.901	0.40, 1.45
						Asian participants:							
						Own- vs. other-race	23	0.90	.375	-0.458	-1.51, 0.59	-0.207	-0.68, 0.26
Matching task	Stimulus ethnicity	1,46	34.81	<.001	.431								
performance	Familiarity	1,46	22.40	<.001	.327								
	Stimulus ethnicity					Cauc. participants:							
	x group	1,46	29.00	<.001	.387	Own- vs. other-race	23	10.21	<.001	0.148	0.12, 0.18	1.879	1.27, 2.61
						Asian participants:							
						Own-vs. other-race	23	0.31	.760	-0.007	-0.05, 0.04	-0.066	-0.50, 0.37
	Stimulus ethnicity					Caucasian IDs:							
	x familiarity	1,46	7.14	.010	.134	Learnt vs. novel	23	3.93	.001	0.116	0.06, 0.18	1.036	0.45, 1.68
						East Asian IDs:							
						Learnt vs. novel	23	1.64	.116	0.030	-0.01, 0.07	0.351	-0.09, 0.81
	Familiarity x trial					Leant IDs:							
	type	1,46	20.66	<.001	.310	Match vs. mismatch	23	0.89	.381	-0.027	-0.09, 0.04	-0.258	-0.86, 0.33
						Novel IDs:							
						Match vs. mismatch	23	1.84	.079	0.088	-0.01, 0.19	0.611	-0.07, 1.32

relative to other-race identities in Caucasian participants, $F(1,318) = 3.29$, $p = .071$, $\eta^2_p = .010$, but significantly larger learning effects for other- relative to own-race faces in East Asian participants, $F(1,318) = 6.58$, $p = .011$, $\eta^2_p = .020$.

4.2.3 Interim summary

Experiment 1 revealed better sorting for own- than other-race identities in Caucasian participants while East Asian participants showed comparable sorting for own- and other-race identities, which is in line with our predictions. In a subsequent matching task, however, we found only limited support for our hypothesis of more pronounced learning effects for own-race identities in Caucasian participants. Unexpectedly, East Asian participants showed clear learning effects for *other*-race identities. In Experiment 2, we investigated learning of own- and other-race facial identities using a recognition instead of a matching task.

4.3 Experiment 2

4.3.1 Method

Participants

24 Caucasian (22 female, 18-25 years, $M_{age} = 19.0$, $SD_{age} = 1.8$) and 24 East Asian students (20 female, 18-21 years, $M_{age} = 18.7$, $SD_{age} = 0.8$) participated in the experiment in exchange for course credit. None of them had taken part in Experiment 1. A further 3 participants were excluded as they failed to follow task instructions. At the time of testing, East Asian participants had been living in the UK (or another country with a predominant Caucasian population) for an average of 8.9 months (*SD*

= 7.4, 1-27 months). None of the Caucasian participants reported having lived in a country with a predominant East Asian population prior to attending university. The study was approved by the ethics committee at Durham University's Psychology department.

Stimuli and Design

The stimulus set was identical to that used in Experiment 1. All aspects of the design were identical to Experiment 1 except that the matching task was replaced by an old/new recognition task. A sequence of 80 single face images was shown on a computer screen. Images were presented at 7 x 11.2 cm on grey background. These images were identical to those presented during the matching task in Experiment 1 (i.e., 40 novel images of identities seen during sorting and 40 images of two previously unseen identities) and presented in random order.

Procedure

The sorting task was performed as described in the procedure section of Experiment 1. For the old/new recognition task, participants were told that they would see a single face image on the screen and that their task was to decide as accurately as possible whether each picture represented a *different* image of one of the two people seen during the sorting task or an unfamiliar person. Stimuli were presented in random order until participants keyed in their response and were separated by a fixation cross presented for 1,000 ms.

Statistical analysis of quality of contact (reported in Table 4.2) and sorting task errors was conducted as described in the respective section of Experiment 1. For the recognition task, following a signal detection theory approach, we calculated the sensitivity measure *d*’ (z-standardised hit rate minus z-standardised false alarm rate, Wickens, 2002). *d*’ data as well as hits and correct rejections (CR) were analysed using a mixed-model ANOVA with the within-subjects factor stimulus ethnicity (Caucasian, East Asian) and the between-subjects factor group (Caucasian, East Asian), and post-hoc comparisons were performed using paired samples t-tests.

4.3.2 Results

For the sake of conciseness, only those results that directly relate to our hypotheses are reported below. A full list of all significant effects is presented in Table 4.2.

A mixed-model ANOVA with the within-subjects factor stimulus ethnicity and the between-subjects factor group on sorting errors yielded a significant interaction, $F(1,46) = 5.11$, $p = .029$, $\eta_p^2 = .100$ (Figure 4.2A). Post-hoc comparisons revealed fewer sorting errors for own- compared to other-race identities in Caucasian participants, $t(23) = 4.55$, $p < .001$, $M_{diff} = 2.583$, 95% CI [1.41, 3.76], Cohen’s d_{unb} = 1.108, 95% CI [0.54, 1.73]. East Asian participants made numerically fewer errors sorting other- compared to own-race faces, although this difference was not significant, $t(23) = 1.06$, $p = .301$, $M_{diff} = -0.708$, 95% CI [-2.09, 0.68], Cohen’s d_{unb} = -0.272, 95% CI [-0.81, 0.25].

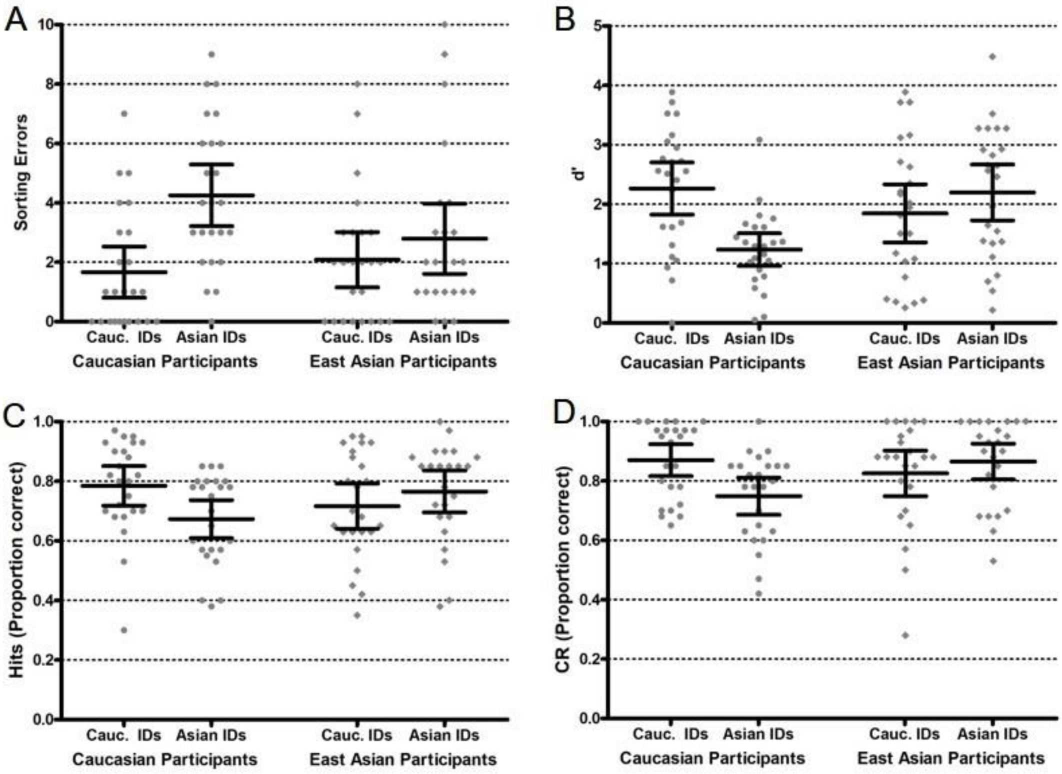

Figure 4.2 Results of Experiment 2. (A) Sorting errors, (B) *d*' data as well as (C) hits and (D) correct rejections during old/new recognition for Caucasian and East Asian identities in Caucasian and East Asian participants. Error bars denote 95% confidence intervals (CI), grey dots represent individual subject data.

A corresponding ANOVA on *d*' (Figure 4.2B) revealed a significant stimulus ethnicity x group interaction, $F(1,46) = 18.41$, $p < .001$, $\eta_p^2 = .286$. Post-hoc contrasts indicated higher sensitivity to own- relative to other-race identities in Caucasian participants, $t(23) = 4.68$, $p < .001$, $M_{\text{diff}} = 1.028$, 95% CI [0.57, 1.48], Cohen's $d_{\text{unb}} = 1.146$, 95% CI [0.57, 1.78], and comparable sensitivity for own- and other-race identities in East Asian participants, $t(23) = 1.50$, $p = .147$, $M_{\text{diff}} = 0.353$, 95% CI [-0.13, 0.84], Cohen's $d_{\text{unb}} = 0.301$, 95% CI [-0.11, 0.72].

We additionally conducted mixed-model ANOVAs with factors stimulus ethnicity and group to analyse hits and CR. For hits (Figure 4.2C), a significant stimulus ethnicity x group interaction was observed, $F(1,46) = 9.02$, $p = .004$, $\eta_p^2 = .164$. Post-hoc comparisons yielded significantly higher hit rates for own- compared to other-race identities in Caucasian participants, $t(23) = 2.78$, $p = .011$, $M_{\text{diff}} = 0.112$, 95% CI [0.03, 0.20], Cohen's $d_{\text{unb}} = 0.701$, 95% CI [0.17, 1.27], but comparable hit rates for own- and other-race identities in East Asian participants, $t(23) = 1.39$, $p = .179$, $M_{\text{diff}} = 0.049$, 95% CI [-0.02, 0.12], Cohen's $d_{\text{unb}} = 0.275$, 95% CI [-0.13, 0.69]. Similarly, for CR (Figure 4.2D), a significant stimulus ethnicity x group interaction was obtained, $F(1,46) = 12.95$, $p = .001$, $\eta_p^2 = .220$, reflecting higher CR rates for own- when compared to other-race identities in Caucasian participants, $t(23) = 4.84$, $p < .001$, $M_{\text{diff}} = 0.121$, 95% CI [0.07, 0.17], Cohen's $d_{\text{unb}} = 0.849$, 95% CI [0.44, 1.31], while no corresponding difference was detected in East Asian participants, $t(23) = 1.06$, $p = .299$, $M_{\text{diff}} = 0.040$, 95% CI [-0.04, 0.12], Cohen's $d_{\text{unb}} = 0.234$, 95% CI [-0.21, 0.69].

A by-item analysis on hit rates confirmed this pattern. We observed a significant stimulus ethnicity x group interaction, $F(1,304) = 41.88$, $p < .001$, $\eta^2_p = .121$. Separate one-way ANOVAs conducted post-hoc revealed significantly higher hit rates for own- than other-race identities in Caucasian participants, $F(1,318) = 15.97$, $p < .001$, $\eta^2_p = .048$, and a trend for higher hit rates for own- compared to other-race identities in East Asian participants, $F(1,318) = 3.85$, $p = .051$, $\eta^2_p = .012$.

4.4 General Discussion

The present experiments investigated differences in perceiving own- and other-race facial identities using images containing natural variability. We further tested whether exposure to within-person variability facilitates identity learning more

Table 4.2 Full list of significant statistical results of Experiment 2.

Analysis	Effect	*df*	*F*	*p*	η^2_p	Post-hoc comparison	*df*	*t*	*p*	M_{diff}	95% CI	d_{unb}	95% CI
Quality of contact	Contact ethnicity x group	1,46	81.06	<.001	.638	Cauc. participants: Own- vs. other-race	23	8.11	<.001	1.667	1.24, 2.09	2.044	1.31, 3.00
						Asian participants: Own- vs. other-race	23	4.90	<.001	1.167	0.67, 1.66	1.573	0.81, 2.42
Sorting task errors	Stimulus ethnicity	1,46	15.18	<.001	.248								
	Stimulus ethnicity x group	1,46	5.11	.029	.100	Cauc. participants: Own- vs. other-race	23	4.55	<.001	2.583	1.41, 3.76	1.108	0.54, 1.73
						Asian participants: Own- vs. other-race	23	1.06	.301	-0.708	-2.09, 0.68	-0.272	-0.81, 0.25
Recognition task													
d'	Stimulus ethnicity	1,46	4.40	.042	.087								
	Stimulus ethnicity x group	1,46	18.41	<.001	.286	Cauc. participants: Own- vs. other-race	23	4.68	<.001	1.028	0.57, 1.48	1.146	0.57, 1.78
						Asian participants: Own- vs. other-race	23	1.50	.147	0.353	-0.13, 0.84	0.301	-0.11, 0.72
hits	Stimulus ethnicity x group	1,46	9.02	.004	.164	Cauc. participants: Own- vs. other-race	23	2.78	.011	0.112	0.03, 0.20	0.701	0.17, 1.27
						Asian participants: Own- vs. other-race	23	1.39	.179	0.049	-0.02, 0.12	0.275	-0.13, 0.69
CR	Stimulus ethnicity x group	1,46	12.95	.001	.220	Cauc. participants: Own- vs. other-race	23	4.84	<.001	0.121	0.07, 0.17	0.849	0.44, 1.31
						Asian participants: Own- vs. other-race	23	1.06	.299	0.040	-0.04, 0.12	0.234	-0.21, 0.69

strongly for own- relative to other-race identities. Participants initially learned own- and other-race faces while sorting ambient images according to identity. In both experiments, Caucasian participants were significantly more accurate when sorting own- relative to other-race identities. In contrast, East Asian participants demonstrated comparable performance. In Experiment 1, we found overall better performance for learnt relative to unfamiliar identities in a subsequent matching task, which replicates previous findings (Andrews et al., 2015). In addition, Caucasian participants showed overall superior matching performance for own- compared to other-race identities while East Asian participants revealed similar performance for the two ethnicities. However, contrary to our hypothesis, East Asian participants demonstrated more pronounced learning effects for other-race faces during the matching task. In Experiment 2, as predicted, Caucasian participants were more accurate at recognising novel instances of own- than of other-race identities previously seen during sorting. By contrast, East Asian participants showed comparable performance for both face categories. These results are discussed in more detail below.

In line with our predictions, Caucasian participants made significantly more errors when sorting other- as compared to own-race faces. This is in line with previous work that used a sorting task in which the number of identities in the set was unknown and demonstrated that participants typically created more other- than own-race identity piles (Laurence et al., 2016; Yan et al., 2016). Together with the present results, these experiments suggest that it is more difficult to perceive identity information from ambient other-race images and to cohere these into identity representations. A similar own-race advantage was also obtained during subsequent matching (Experiment 1). Caucasian participants again showed significantly better matching performance for own- relative to other-race faces, independent of whether the identities were learnt or novel, which is in line with previous work (Kokje, Bindemann, & Megreya, 2018; Megreya et al., 2011). Interestingly, a markedly different pattern was obtained for East Asian participants. In both experiments, East Asian participants showed comparable performance for own- and other-race identities during the initial sorting task, and this pattern was also observed subsequently during matching (Experiment 1). The absence of a clear own-race advantage in this group presumably resulted from their increased experience with Caucasian people while living in the UK. This interpretation is in line with previous findings of reduced or even absent own-race biases in participants with enhanced expertise for other-race faces (Chiroro & Valentine, 1995; Hancock & Rhodes, 2008; Wiese et al., 2014). These findings are also in accordance with a perceptual expertise explanation of the ORB, as they reveal that it is more difficult to extract identity information from a set of other-race compared to own-race face images, unless participants have had extensive other-race contact.

As detailed in the introduction, a particular motivation for the present study was to investigate whether it is harder to learn novel other-race facial identities. Therefore, in Experiment 1, we directly compared learning effects for own- and other-race faces in both participant groups. As predicted, Caucasian participants showed numerically larger learning effects for own- relative to other-race faces. Although the direct statistical comparison of own- and other-race learning effects did not result in a significant effect, inspection of Figure 4.1C reveals that only the confidence interval for the other-race condition includes zero (and is therefore not significantly different from zero). Unexpectedly, however, East Asian participants yielded clearly larger learning effects for *other*- relative to own-race faces.

Using an old/new recognition memory procedure, we observed a clear own-race advantage in face identity learning in Caucasian participants in Experiment 2, which is in line with our predictions. More specifically, Caucasian participants were more accurate at recognising novel instances of recently learnt own-race than other-race faces, which is also in line with previous work (e.g., Zhou et al., 2018). In contrast, East Asian participants again showed comparable performance for both face categories, which, as discussed above, might reflect their increased contact with Caucasian people.

In sum, while Caucasian participants showed an own-race advantage in both experiments, East Asian participants demonstrated an other-race learning advantage in Experiment 1 but comparable learning of own- and other-race identities in Experiment 2. These latter results are hard to accommodate with an explanation of the ORB that solely relies on perceptual expertise. Instead, these findings likely reflect a combination of East Asian participants' considerable expertise with the other-race category and increased motivation to individuate other-race faces. At the time of testing, East Asian participants had acquired substantial experience with Caucasian faces due to living in the UK, and most likely had also realised that Caucasian faces are hard to recognise for them. Therefore, they may have put more effort into processing other-race faces (for related empirical evidence, see Wan, Crookes, Reynolds, Irons, & McKone, 2015).

Importantly, however, the extent to which motivation to individuate modulates performance at test seems to depend on specific task characteristics. More specifically, in the matching task of Experiment 1, the influence of previous learning is indirect, as a decision about two simultaneously presented stimuli is affected by a face representation established during learning. In other words, all information necessary for the task is in principle available in the display, but previous learning about within-person variability improves performance. Under these conditions, increased motivation or attention to other-race faces appears to be particularly beneficial, which may in turn enhance the benefit from previous learning. By contrast, explicit old/new recognitions (as used in Experiment 2) require a familiarity decision to a single face stimulus, and an “old” response is made whenever the stimulus sufficiently activates a recently formed representation. Our data suggest that this process of directly comparing a face with a memory representation is harder to modulate by increased motivation relative to the matching task. We acknowledge, however, that this interpretation is speculative at present and needs to be tested in future studies.

If motivation modulated performance of East Asian participants, it appears reasonable to ask whether the clear own-race advantages in Caucasian participants might have been related to *reduced* motivation to individuate other-race faces (Hugenberg et al., 2010). While this possibility cannot be completely ruled out based on the present data, we do not think that reduced motivation is a likely explanation for the present findings in this participant group. The experimental tasks used in the present experiments, i.e., sorting, matching and recognition from novel images, explicitly ask for the processing of individual identity, and processing of other-race faces at a categorical level, as suggested by socio-cognitive accounts, would not have been sufficient to reach the overall high performance levels observed here. We also note that own- and other-race faces were presented in separate blocks, further stressing the importance of individuating both ethnic groups. We therefore suggest that Caucasian participants were not *able* to sort, match and recognise other-race faces as accurately as own-race faces, and that this reduced ability resulted from their reduced perceptual expertise.

Finally, we note that in the present study, all images were presented in greyscale rather than in colour. This decision was practical rather than driven by theoretical considerations. The image sets from this study have also been used in experiments using event-related brain potentials (ERPs). Using greyscale images allows to more easily control basic physical stimulus properties, such as luminance and contrast, which can be important for ERP experiments. Previous work has shown that performance in matching tasks with own-race faces is unaffected by whether images are shown in greyscale or colour (e.g., Bruce et al., 1999). Moreover, a systematic literature review suggested that perceptual processing of own- and other-race faces is not affected by colour versus greyscale format (see Wiese, 2013). We therefore do not think that our choice of using greyscale images substantially affected our results.

In conclusion, the present study offers some support for the idea that individual other-race faces are harder to learn than own-race faces. This own-race advantage, however, was observed only in Caucasian participants who had limited contact with other-race individuals. In contrast, East Asian participants with substantial other-race contact were able to learn individual other-race faces as well as own-race faces. In addition, in this participant group, increased motivation to learn other-race identities may even result in more pronounced learning effects. Thus, the present study further supports recent propositions that perceptual expertise and socio-cognitive factors can interact in specific settings (Wan et al., 2015). Finally, our findings may inform further research in applied contexts, such as eyewitness testimony or passport control. Whereas participants without specific other-race expertise are likely to be less accurate in such applied situations, a combination of increased motivation and expertise may, under certain conditions, not only overcome but even overcompensate any disadvantage for other-race faces.

5 Learning own- and other-race facial identities: Evidence from event-related brain potentials

Exposure to varying images of the same person encourages the formation of a representation that is sufficiently robust to allow recognition of previously unseen images of this person. While behavioural work suggests that face identity learning is harder for other-race faces, the present experiment investigated the neural correlates underlying own- and other-race face learning. Participants sorted own- and other-race identities into separate identity clusters and were further familiarised with these identities in a matching task. Subsequently, we compared event-related brain potentials (ERPs) for learnt and previously unseen identities. We observed better sorting and matching for own- than other-race identities, and behavioural learning that was restricted to own-race identities. Early perceptual ERPs showed clear learning effects for own-race faces only. The N250, a component associated with face learning, was generally more negative for learnt than novel identities, but also for other-race faces overall. ERP findings thus suggests a processing advantage for own-race identities at an early perceptual level whereas later correlates of identity learning were unaffected by ethnicity. The results suggest clear learning advantages for own-race identities, which underscores the importance of perceptual expertise in the own-race bias.

5.1 Introduction

People are better at remembering faces from their own compared to a different ethnic group, a well-established phenomenon called the own-race bias (ORB, or other-race effect; Malpass & Kravitz, 1969; Meissner & Brigham, 2001). The ORB is commonly studied using pre-experimentally unfamiliar faces that are learnt from a single picture, and these pictures subsequently have to be recognised among newly presented distractors. However, experiments using this basic paradigm will only give limited insight into how own- and other-race faces are learnt and recognised in real life. These limitations stem from fundamental differences in unfamiliar and familiar face recognition, and from recent findings demonstrating how faces become familiar. While we can easily recognise the people we know from a wide range of different images, seeing that different pictures show the same unfamiliar person can be very difficult (Bruce et al., 1999; Jenkins, White, Van Montfort, & Burton, 2011). Face learning therefore reflects the establishment of representations that allow for recognition independent of a specific image (Jenkins & Burton, 2011). Nonetheless, studies on the ORB have typically ignored image-independent face recognition, which is arguably critical for identification in applied contexts, such as eyewitness testimony. Similarly, studies on the neural correlates of the ORB have largely focused on pictorial rather than face learning (e.g., Golby, Gabrieli, Chiao, & Eberhardt, 2001; Herzmann, Willenbockel, Tanaka, & Curran, 2011; Wiese, Kaufmann, & Schweinberger, 2014). The present study thus aimed to fill this gap by examining the neural processes accompanying own- and other-race face identity learning.

The few available studies on image-independent processing of other-race faces suggest that difficulties in unfamiliar face recognition are even more pronounced for faces from different ethnic groups. First, face matching tasks in which participants have to indicate whether two simultaneously presented pictures show the same person or not (see e.g., Megreya & Burton, 2006) are surprisingly difficult, even for own-race faces. However, a further decrease in performance has been observed for other-race faces (Kokje, Bindemann, & Megreya, 2018; Megreya, White, & Burton, 2011). Second, when participants are presented with printed cards showing multiple images of two different identities and are asked to sort these cards into as many piles as they perceive identities in the set, they often drastically overestimate the true number of identities (Jenkins et al., 2011). Yet participants create even more identity clusters when the faces are from a different ethnic group (Laurence, Zhou, & Mondloch, 2016; Yan, Andrews, Jenkins, & Young, 2016; Zhou & Mondloch, 2016).

These findings clearly demonstrate difficulties with unfamiliar other-race facial identities at a perceptual level, but they also suggest that learning new facial identities from a different ethnic group might be more difficult. Getting to know how different a face can look in different pictures appears to be key to acquiring image-independent familiarity with that face (Bruce, 1994; Burton, 2013; Burton, Kramer, Ritchie, & Jenkins, 2016; Burton, Schweinberger, Jenkins, & Kaufmann, 2015). Studies examining face learning therefore often use so-called ambient images (see Figure 1.1 in Chapter 1), which capture a high degree of "naturalistic" variability in appearance, e.g., with respect to lighting, viewing angle, or emotional expressions. Of particular relevance for the present study, Andrews, Jenkins, Cursiter, and Burton (2015) presented participants with multiple cards showing ambient images of two different identities and, in contrast to the study by Jenkins and colleagues (2011) discussed above, informed the participants about the true number of identities in the set and specifically instructed them to sort the images into two clusters, one for each identity. In a subsequent matching task, novel exemplars of the identities seen during sorting were matched more accurately than images of unfamiliar faces (Andrews, Burton, Schweinberger, & Wiese, 2017; Andrews et al., 2015). These findings indicate that exposure to within-identity variability during sorting results in the formation of image-independent representations. At the same time, given that sorting images according to identity is more difficult for other-race faces (e.g., Yan et al., 2016), it might also be harder to learn other-race faces through exposure to within-identity variability.

Support for the suggestion that other-race identities are harder to learn from highly variable images comes from two recent studies which directly compared own- and other-race face identity learning. First, Hayward and colleagues found that participants learned other-race identities less efficiently than own-race identities, and that training generalised more poorly to novel exemplars of the learnt other- relative to own-race identities (Hayward, Favelle, Oxner, Chu, & Lam, 2017). Second, better learning of own- relative to other-race identities has also been observed by Zhou, Matthews, Baker, and Mondloch (2018). These authors found that a higher degree of variability during learning was needed for later image-independent recognition of other- as compared to own-race identities. These learning difficulties associated with other-race faces have been interpreted to reflect reduced perceptual expertise with the other-race category (e.g., Proietti, Laurence, Matthews, Zhou, & Mondloch, 2018; Zhou et al., 2018). At the same time, Cavazos, Noyes, and O'Toole (2018) found that own- and other-race faces equally benefitted from multi-image training. Although an ORB was observed, the presentation of multiple images during learning led to face representations that facilitated subsequent recognition of novel exemplars of both own- and other-race faces.

The aim of the present study was to investigate the neural correlates of face identity learning for own- and other-race faces. While face processing is thought to consist of a number of successive stages (see e.g., Bruce & Young, 1986; Schweinberger & Neumann, 2016), behavioural measures only inform about the outcome of these various processing steps. Here, we analysed event-related brain potentials (ERPs) to more directly determine at what processing stage differences between own- and other-race face learning would occur. ERPs reflect transient voltage changes in the electroencephalogram (EEG) that are time-locked to a specific event, e.g., the presentation of a visual stimulus. They consist of positive and negative deflections, so-called components, which are associated with distinct stages of stimulus processing, in this case, the processing of faces. ERPs therefore provide an excellent tool for the purpose of the present study.

The first face-sensitive ERP component is the N170, a negative deflection peaking approximately 170 ms after stimulus onset at occipito-temporal electrodes. N170 is more negative for faces than for other classes of objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996), but usually considered to be insensitive to familiarity (Bentin & Deouell, 2000; Eimer, 2000a; Schweinberger, Pfütze, & Sommer, 1995; Zimmermann & Eimer, 2013, 2014). Hence, it is typically interpreted to reflect processes prior to the identification of an individual face (but see Schweinberger & Neumann, 2016, for a detailed discussion of identity adaptation effects), such as structural encoding or the detection of a face-like pattern (Eimer, 2000b; Eimer, 2011). N170 is often more negative for other- relative to own-race faces (e.g., Cassidy, Boutsen, Humphreys, & Quinn, 2014; Herrmann et al., 2007;

Stahl, Wiese, & Schweinberger, 2010; Wiese & Schweinberger, 2018), which presumably indicates more effortful structural processing of other-race faces. However, some studies did not observe ethnicity effects in N170 (e.g., Gajewski, Schlegel, & Stoerig, 2008; Herzmann et al., 2011; Wiese, Stahl, & Schweinberger, 2009), which may, at least partly, reflect differential task demands (Senholzi & Ito, 2013; Wiese, 2013).

N170 is immediately followed by a positive deflection, the occipito-temporal P2, peaking roughly 200 ms after stimulus onset. Generally, P2 amplitude is more positive for "typical" compared to "atypical" faces. For example, more positive P2 amplitudes have been observed for veridical relative to spatially caricatured faces (Schulz, Kaufmann, Kurt, & Schweinberger, 2012). In addition, P2 is usually more positive for own- when compared to other-race faces (Stahl et al., 2010; Wiese & Schweinberger, 2018), although this effect was observed to be attenuated in participants with substantial other-race contact (Stahl, Wiese, & Schweinberger, 2008). Moreover, shifting participants' attention to individual rather than ethnic category information eliminated this P2 effect (Stahl et al., 2010). These findings suggest that ethnicity effects in the P2 time range are shaped by both long-term experience and current task demands.

The subsequent N250 is the earliest component consistently associated with the processing of facial identity. More negative N250 amplitudes have been observed for famous (Andrews et al., 2017; Gosling & Eimer, 2011) and personally familiar (Wiese et al., in press) relative to unfamiliar faces. Similarly, N250 is more negative for immediate repetitions of faces relative to conditions in which two different faces are presented in succession. This so-called N250r (r for repetition; Begleiter, Porjesz, & Wang, 1995; Bindemann, Burton, Leuthold, & Schweinberger, 2008; Herzmann, Schweinberger, Sommer, & Jentzsch, 2004; Schweinberger et al., 1995) has been interpreted to reflect access to perceptual face representations. More negative amplitudes in the N250 time range have also been observed for other- relative to own-race faces (Herzmann et al., 2011; Stahl et al., 2010; Wiese et al., 2014; Wiese & Schweinberger, 2018), which may reflect more effortful processing of individual other-race faces (Herzmann, 2016).

The N250 has also been linked to face learning, with increased amplitudes for newly learnt relative to novel faces (Kaufmann, Schweinberger, & Burton, 2009; Tanaka, Curran, Porterfield, & Collins, 2006), and these N250 learning effects were evident across different images of the respective faces (Kaufmann et al., 2009). Interestingly, learning effects within the N250 time range have also been observed following individuation training with a specific category of other-race faces (Tanaka & Pierce, 2009). To date, only one previous study investigated ERP correlates of identity learning using ambient images (Andrews et al., 2017). After sorting ambient images of two identities into respective identity clusters, images seen during the sorting task elicited more negative N250 amplitudes compared to images of novel identities. More importantly, these learning effects were highly similar for images presented during sorting and a new set of images of the learnt identities, suggesting the establishment of new image-independent representations.

The present study used a paradigm similar to Andrews et al. (2017) to study the neural correlates of own- and other-race face identity learning. Specifically, we sought to investigate whether learning is more challenging for faces of a different ethnic group and, if so, at what neural processing stage such ethnicity-related difficulties would manifest. Participants first sorted ambient images of two identities into two separate identity clusters. Subsequently, to promote further familiarisation with these identities, particularly in light of the above-described difficulties with other-race faces, participants completed four blocks of a matching task during which the sorting task images were repeatedly presented. Feedback was provided after each trial. Finally, participants watched a sequence of faces while their EEG was recorded. Stimuli in this task consisted of the images seen during sorting/matching (learnt ID/same images), a new set of images of the identities presented during sorting/matching (learnt ID/different images), and images of two unfamiliar faces (novel ID). This sequence of tasks was completed with both own-race and other-race identities.

In line with previous findings (e.g., Laurence et al., 2016), we expected better sorting of own- than other-race identities. Based on recent findings that other-race faces are harder to learn than own-race faces (e.g., Zhou et al., 2018), we also expected overall better matching accuracy with own-race faces and a stronger performance increase over blocks for this face category. With respect to ERPs, we expected to replicate the findings of Andrews et al. (2017) for own-race faces. Specifically, if the sorting and matching tasks triggered the formation of face representations, more negative N250 amplitudes would be expected for learnt ID/same images compared to novel ID images. In addition, if these representations were sufficiently robust to allow for the recognition of novel own-race exemplars (e.g., Andrews et al., 2015; 2017), we would expect N250 amplitudes of learnt ID/different images to be highly similar to those of learnt ID/same images. However, as other-race face learning has been found to not readily generalise to novel instances (e.g., Hayward et al., 2017), we anticipated N250 learning effects to be largely restricted to those other-race images presented during sorting and matching.

5.2 Method

5.2.1 Participants

20 participants who were undergraduate and postgraduate students as well as staff members (10 female, 18 – 37 years, M_{age} = 23.6, SD_{age} = 5.8) at Durham University gave written informed consent to take part in the experiment. All had a Caucasian ethnic background. Participants reported normal or corrected-to-normal vision, and no neurological or psychiatric conditions. All were right-handed as assessed by the Edinburgh Handedness questionnaire (Oldfield, 1971). Participants received course credit or a monetary compensation of £14 for taking part. The study was approved by the local Ethics Committee at Durham University's Department of Psychology.

5.2.2 Stimuli and Design

We compiled 40 images of each of four Caucasian and four East Asian male models via a Google image search (see also Tüttenberg & Wiese, in revision). For each identity, the first 40 images of each identity were chosen where the face covered an area of at least 190 x 285 pixels and facial features were not covered by e.g., sunglasses. All images were converted to grey scale and framed within an area of 190 x 285 pixels. In addition, for the sorting task (see below), 20 images for each identity were re-sized to 3 x 4 cm, printed, laminated and cut out to create a single picture card for each image. There were also 12 images of butterflies (previously used in Andrews et al., 2017). After completion of the main experiment, participants were asked to rate the quality of contact with Caucasian and East Asian people on a scale from 1 to 4 (1 – very superficial, 2 – rather superficial, 3 – rather intense, 4 – very intense; Wiese, 2012).

For each identity, images were randomly divided into two sets (A, B) of 20 images each. The identities within each ethnic group were joined to pairs (Caucasian ID1/2, Caucasian ID3/4, East Asian ID1/2, and East Asian ID3/4). In total, there were four different image sets for each ethnic group (sets A and B for ID1/2 and ID3/4, respectively).

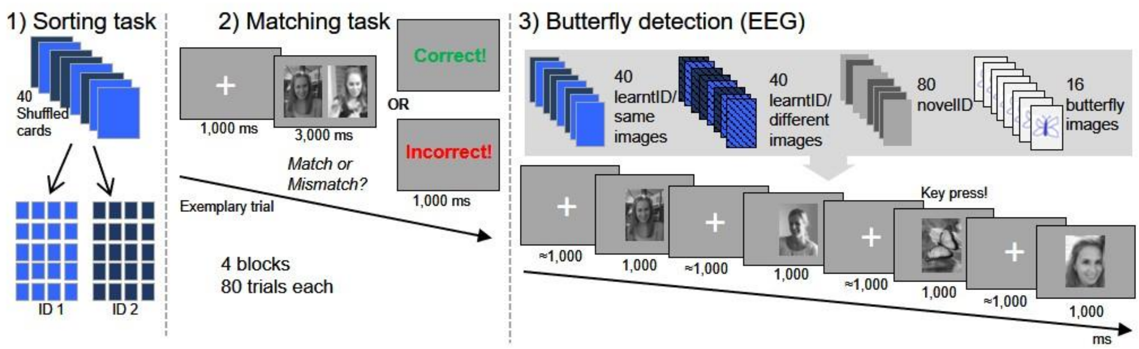

Figure 5.1 Overview of procedure. For more detailed information, refer to main text. For copyright reasons, images shown in the figure are not those used in the experiment. Images are reprinted with full permission of the depicted persons.

A sequence of three different tasks was employed, a sorting task, a matching task and a final butterfly detection task (Figure 5.1). This sequence was completed twice, once with Caucasian and once with East Asian identities in separate blocks. The order (Caucasian first, East Asian first) was counterbalanced across participants.

For the sorting task, Set A of one identity pair (ID1/2A, or ID3/4A) for the respective ethnic group was selected. The identity set used in the sorting task was counterbalanced across participants.

The subsequent matching task comprised four blocks with 80 trials each. These were 40 match trials (20 for each of the two identities encountered in the sorting task) and 40 mismatch trials in which one image of each of the two identities was shown. Selected images were those presented during sorting to encourage continued familiarisation with the identities. Each image was presented four times per block, twice in match and mismatch trials, respectively. Although specific images were repeated both within and across blocks, two individual images were never shown together more than once. Images were presented side-by-side on dark grey background on a computer monitor. Both images were displayed at 5.6 x 8.4 cm with a 3.5 cm gap between images. Each image had equal probability to appear as left or right image.

The final picture viewing task consisted of 176 trials, i.e., 40 trials comprising the images of the two identities seen during sorting and matching (learnt ID/same images; e.g., ID1/2A), 40 trials showing new images of the identities seen during sorting and matching (learnt ID/different images; e.g., ID1/2B), and 80 trials comprising images of two previously unseen identities (novel ID, e.g., ID3/4A and B). The remaining 16 trials showed images of butterflies which were not analysed and only included to create task demands (see below). Images were presented on dark grey background in the centre of a computer monitor within an area of 195 x 280 pixels (5.6 x 8.4 cm), corresponding to a viewing angle of 3.21° x 4.81° at a viewing distance of 100 cm, which was maintained with a chin rest.

5.2.3 Procedure

After providing written informed consent, participants were prepared for EEG recording. They then completed the first sorting task. Participants received a pile of

40 shuffled cards of two identities and were told that the images were of two different people with 20 images per identity. They were asked to sort these images into two separate identity clusters.

Following the sorting task, participants were seated in front of a computer monitor to engage in the matching task. Participants saw pairs of faces and had to judge as accurately as possible via key presses whether the two faces showed the same or different persons. Key assignment to match and mismatch responses was counterbalanced across participants. Images were presented for 3,000 ms, preceded by a fixation cross shown for 1,000 ms. After each trial, participants received feedback (‘Correct!’ or ‘Incorrect!’ in green or red letters, respectively; or ‘No response detected’ (also in red) if participants failed to submit their answer within 3,000 ms) which was presented for 1,000 ms.

Finally, in the butterfly detection task, participants saw a sequence of images and were instructed to press a key as fast and as accurately as possible whenever an image of a butterfly was presented. Images were shown for 1,000 ms and preceded by a fixation cross which was presented for an average duration of 1,000 ms (randomly jittered between 800 and 1,200 ms). Images were presented in random order. Afterwards, participants completed the second block with stimuli from the respective other ethnic group.

5.2.4 EEG recording and data analysis

EEG was recorded from 64 sintered Ag/Ag-Cl electrodes with an ANT Neuro system (Enschede, Netherlands). An electrode on the forehead served as ground and Cz as recording reference. EEG was sampled at a rate of 512 Hz (DC to 120 Hz).

Recording sites corresponded to an extended 10 – 20 system. Blink correction was performed using the algorithm implemented in BESA 6.3 (Gräfelfing, Germany). EEG was segmented from -200 until 1,000 ms relative to stimulus onset whereby the first 200 ms served as baseline. Artefact rejection was carried out using an amplitude threshold of 100 µV and a gradient criterion of 75 µV. All remaining trials were recalculated to average reference, digitally low-pass filtered at 40 Hz (12 dB/oct, zero phase shift) and then averaged according to experimental conditions. The average number of trials was 35.1 (*SD* = 6.0) for learnt ID/same images, 34.5 (*SD* = 6.3) for learnt ID/different images, and 69.7 (*SD* = 11.4) for novel ID in the own-race identity condition, and 34.9 (*SD* = 5.4) for learnt ID/same images, 34.9 (*SD* = 5.1) for learnt ID/different images, and 70.1 (*SD* = 10.4) for novel ID in the other-race identity condition.

In the averaged waveforms, mean amplitudes for N170 (130 – 180 ms), P2 (180 – 220 ms) and N250 components (280 – 400 ms) at P9/10 and TP9/10 were calculated. Time windows for the respective components were selected based on visual inspection of the grand averages.

Statistical analyses were performed using repeated measures analyses of variance (ANOVA). Matching task accuracy was analysed using the within-subjects factors ethnicity (own-race, other-race), trial type (match, mismatch) and block (1, 2, 3, 4). Post-hoc comparisons as well as analysis of quality of contact, sorting task errors and accuracy of butterfly detection were performed using paired samples t-tests. EEG data were analysed using repeated measures ANOVAs with the within-subjects factors hemisphere (left, right), site (TP, P), ethnicity (own-race, other-race) and ID type (learnt ID/same images, learnt ID/different images, novel ID). Degrees of freedom were adjusted using the Greenhouse-Geisser procedure whenever appropriate.

Following an estimation approach in data analysis (see e.g., Cumming, 2012; Cumming & Calin-Jageman, 2017), we report effect sizes and appropriately sized confidence intervals (CI) throughout. As suggested by these authors, 95% CIs for Cohen's *d* for paired samples t-tests were corrected for bias and computed by using the mean SD rather than the SD of the difference as the denominator (Cohen's d_{unb}), which were computed using ESCI (Cumming & Calin-Jageman, 2017). 90% CIs for partial eta squared (η_p^2) were calculated using scripts by M.J. Smithson (http://www.michaelsmithson.online/stats/CIstuff/CI.html).

5.3 Results

5.3.1 Behavioural results

Quality of contact

Participants reported higher quality of contact with own-race (M = 3.300, 95% CI [2.93, 3.68]) than with other-race people (M = 1.900, 95% CI [1.45, 2.35]), $t(19) = 3.99$, $p < .001$, $M_{diff} = 1.400$, 95% CI [0.67, 2.14], Cohen's $d_{unb} = 1.512$, 95% CI [0.64, 2.48].

Sorting errors

Participants made fewer errors when sorting own- compared to other-race identities, $t(19) = 4.62$, $p < .001$, $M_{diff} = 2.900$, 95% CI [1.59, 4.21], Cohen's d_{unb} = 1.165, 95% CI [0.56, 1.85] (see Figure 5.2a).

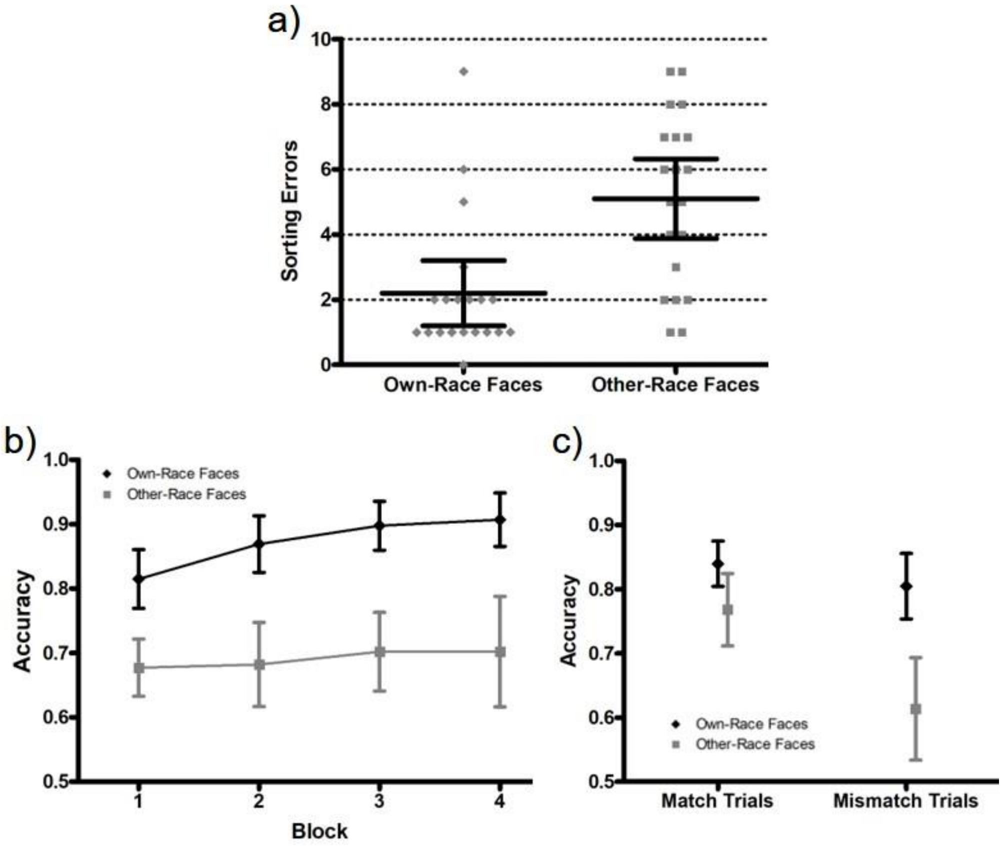

Figure 5.2 Behavioural results. (a) Sorting and (b, c) Matching task results. Error bars denote 95% confidence intervals (CIs), grey squares in (a) depict individual subjects' data.

Matching task

A repeated measures ANOVA with the within-subjects factors ethnicity (own-race, other-race), trial type (match, mismatch) and block (1, 2, 3, 4) on matching task performance yielded significant main effects of ethnicity, trial type and block, reflecting better performance for own- relative to other-race identities, $F(1,19) = 41.60$, $p < .001$, $\eta_p^2 = .686$, 90% CI [0.43, 0.79], for match compared to mismatch trials, $F(1,19) = 15.77$, $p = .001$, $\eta_p^2 = .454$, 90% CI [0.16, 0.62], and an increase in performance across blocks, $F(3,57) = 8.21$, $p = .001$, $\eta_p^2 = .302$, 90% CI

[0.12, 0.42]. In addition, the ethnicity x block interaction approached significance, $F(3,57) = 2.39$, $p = .078$, $\eta_p^2 = .112$, 90% CI [0.00, 0.21] (see Figure 5.2b). We further calculated pairwise comparisons to test our a priori prediction of larger performance increases across blocks for own- than other-race faces. For own-race identities, performance increased from block 1 to block 2, $t(19) = 3.79$, $p = .001$, $M_{diff} = 0.054$, 95% CI [0.02, 0.08], Cohen's $d_{unb} = 0.483$, 95% CI [0.19, 0.80], from block 2 to block 3, $t(19) = 2.25$, $p = .036$, $M_{diff} = 0.029$, 95% CI [0.01, 0.06], Cohen's $d_{unb} = 0.301$, 95% CI [0.02, 0.60], but not from block 3 to block 4, $t(19) = 0.84$, $p = .413$, $M_{diff} = 0.010$, 95% CI [-0.01, 0.03], Cohen's $d_{unb} = 0.106$, 95% CI [-0.15, 0.37]. For other-race identities, no improvement in performance was detected across blocks (block 1 to block 2, $t(19) = 0.27$, $p = .794$, $M_{diff} = 0.005$, 95% CI [-0.04, 0.05], Cohen's $d_{unb} = 0.039$, 95% CI [-0.26, 0.34]; block 2 to block 3, $t(19) = 1.11$, $p = .282$, $M_{diff} = 0.020$, 95% CI [-0.02, 0.06], Cohen's $d_{unb} = 0.135$, 95% CI [-0.11, 0.39]; block 3 to block 4, $t(19) = 0.01$, $p = .999$, $M_{diff} = 0.001$, 95% CI [-0.04, 0.04], Cohen's $d_{unb} = 0.001$, 95% CI [-0.22, 0.22]).

Furthermore, two significant two-way interactions were observed. First, there was a significant ethnicity x trial type interaction, $F(1,19) = 9.95$, $p = .005$, $\eta_p^2 = .344$, 90% CI [0.07, 0.54], Follow-up tests revealed significant effects of ethnicity for both match, $t(19) = 4.35$, $p < .001$, $M_{diff} = 0.121$, 95% CI [0.06, 0.18], Cohen's $d_{unb} = 1.128$ [0.52, 1.81], and mismatch trials, $t(19) = 6.18$, $p < .001$, $M_{diff} = 0.241$, 95% CI [0.16, 0.32], Cohen's $d_{unb} = 1.506$, 95% CI [0.86, 2.26], with larger ethnicity effects for the latter (see Figure 5.2c). Second, a significant block x trial type interaction was observed, $F(3,57) = 8.83$, $p < .001$, $\eta_p^2 = .317$, 90% CI [0.13, 0.43]. Follow-up tests revealed higher accuracy for match compared to mismatch trials, which was significant from blocks 1 to 3 (1: $t(19) = 6.05$, $p < .001$, $M_{diff} = 0.158$, 95% CI [0.10, 0.21], Cohen's d_{unb} = 1.532 [0.86, 2.31], 2: $t(19) = 3.15$, $p = .005$, $M_{diff} = 0.089$, 95% CI [0.03, 0.15], Cohen's d_{unb} = 0.715, 95% CI [0.22, 1.26], 3: $t(19) = 7.64$, $p = .012$, $M_{diff} = 0.077$, 95% CI [0.02, 0.14], Cohen's d_{unb} = 0.679, 95% CI [0.15, 1.25], and but only approached significance in block 4, $t(19) = 2.09$, $p = .051$, $M_{diff} = 0.055$, 95% CI [-0.01, 0.11], Cohen's d_{unb} = 0.390, 95% CI [-0.01, 0.81], reflecting an increase in accuracy on mismatch trials while accuracy on match trials remained relatively stable.

Butterfly detection

Accuracy in butterfly detection approached ceiling and was highly similar for own- ($M = 0.991$, 95% CI [0.98, 1.00]) and other-race blocks ($M = 0.988$, 95% CI [0.97, 1.00]), $t(19) = 0.30$, $p = .772$, $M_{diff} = 0.003$, 95% CI [-0.02, 0.02], Cohen's d_{unb} = 0.095, 95% CI [-0.56, 0.76].

5.3.2 ERP results

For the sake of conciseness, only significant main effects of, and interactions involving, the experimental factors ethnicity and ID type are reported in the main text. All other significant results, and results for the main effects of the experimental factors that did not reach significance, are reported in Table 5.1. ERP results are depicted in Figures 5.3 and 5.4.

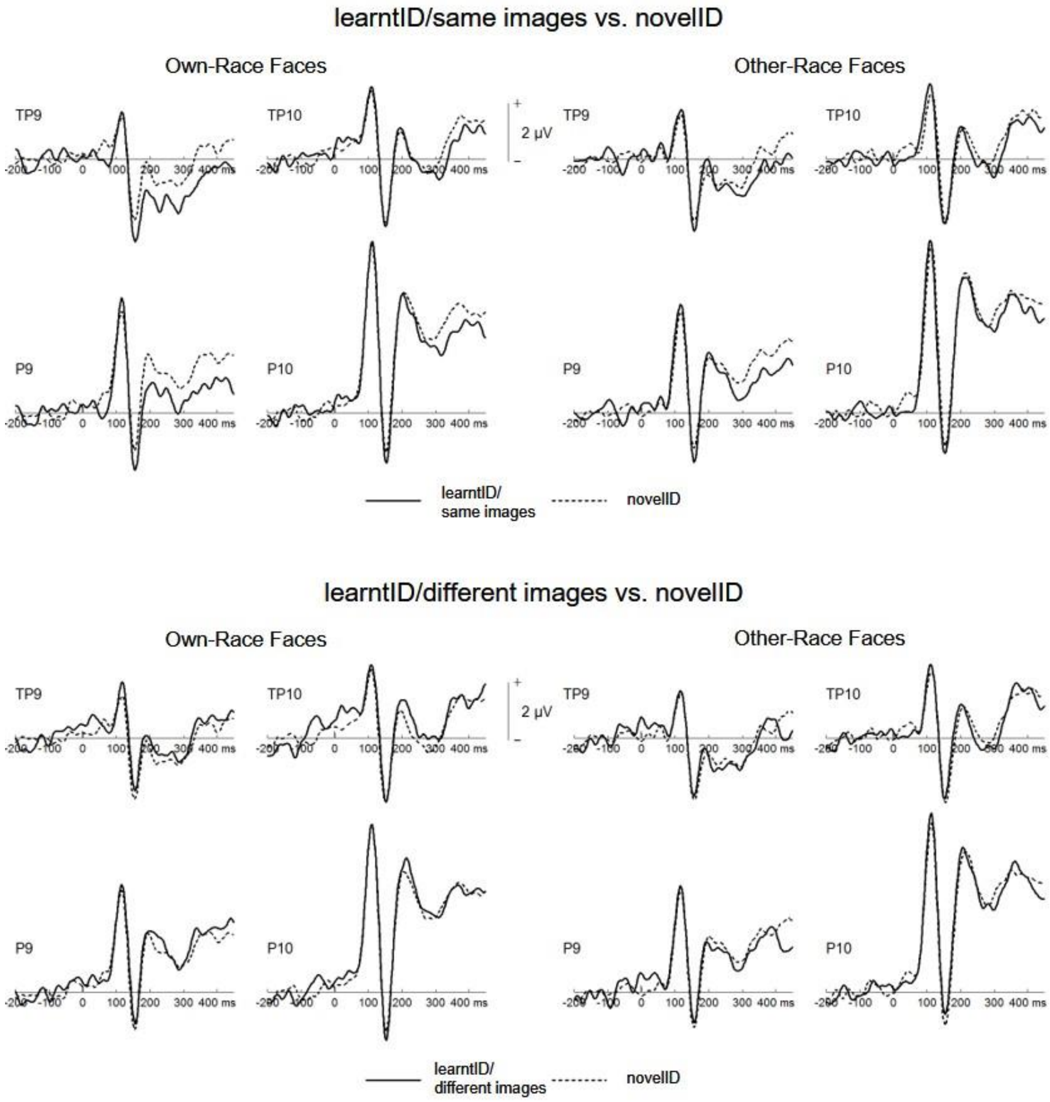

Figure 5.3 Grand average ERPs. Upper half shows grand average ERPs for learnt ID/same images and novel ID, lower half shows grand average ERPs for learnt ID/different images and novel ID for own- and other-race faces, at electrodes P9/10 and TP9/10

Table 5.1 Additional ERP results not reported in the main text.

ERP	Effect	Follow-up	*df*	*F*	*p*	η^2_p	90% CI	Mean (μV)	90% CI
N170	Site		1,19	14.08	.001	.426	0.13, 0.60	TP: -0.78	-1.61, 0.06
								P: 0.66	-0.79, 2.11
	Ethnicity		1,19	0.15	.703	.008	0.00, 0.15	Own: -0.10	-1.23, 1.03
								Other: -0.02	-1.16, 1.12
	Ethnicity x Site x ID type		2,38	2.69	.080	.124	0.00, 0.27		
		Own-race / TP9/10	2,38	2.61	.087	.121	0.00, 0.26	learntID/same: -1.08	-2.02, -0.14
								learntID/diff.: -0.50	-1.42, 0.41
								novelID: -0.80	-1.70, 0.11
		Own-race / P9/10	2,38	2.91	.067	.133	0.00, 0.28	learntID/same: 0.32	-1.12, 1.76
								learntID/diff.: 0.78	-0.63, 2.20
								novelID:0.68	-0.84, 2.19
		Other-race / TP9/10	2,38	0.48	.577	.025	0.00, 0.11	learntID/same: -0.87	-1.87, 0.13
								learntID/diff.: -0.64	-1.52, 0.24
								novelID: -0.68	-1.66, 0.10
		Other-race / P9/10	2,38	2.34	.110	.110	0.00, 0.25	learntID/same: 0.47	-1.05, 1.98
								learntID/diff.: 0.98	-0.57, 2.52
								novelID: 0.74	0.76, 2.25
P2	Hemisphere		1,19	8.28	.010	.303	0.05, 0.51	Left: 0.50	-0.60, 1.59
								Right: 2.42	0.75, 4.09
	Site		1,19	63.76	<.001	.770	0.57, 0.84	TP: 0.12	-0.87, 1.11
								P: 2.80	1.29, 4.31
	Ethnicity		1,19	0.27	.609	.014	0.00, 0.18	Own-race: 1.41	0.21, 2.60
								Other-race: 1.51	0.22, 2.80
	ID type		2,38	1.76	.187	.085	0.00, 0.21	learntID/same: 1.30	0.03, 2.56
								learntID/diff.: 1.64	0.39, 2.90
								novelID: 1.44	0.22, 2.66
	Ethnicity x Site		1,19	3.52	.076	.156	0.00, 0.38		
		TP9/10	1,19	0.01	.942	.001	0.00, 0.01	Own: 0.13	-0.85, 1.10
								Other: 0.11	-0.94, 1.16
		P9/10	1,19	1.13	.301	.056	0.00, 0.26	Own: 2.68	1.23, 4.15
								Other: 2.92	1.33, 4.51
N250	Hemisphere		1,19	7.66	.012	.287	0.04, 0.50	Left: 0.40	-0.58, 1.37
								Right: 1.90	0.89, 2.90
	Site		1,19	75.64	<.001	.799	0.62, 0.86	TP: -0.05	-0.80, 0.70
								P: 2.34	1.38, 3.29
	Ethnicity		1,19	1,19	.181	.092	0.00, 0.31	Own: 1.03	0.22, 1.83
								Other: 1.26	0.41, 2.11

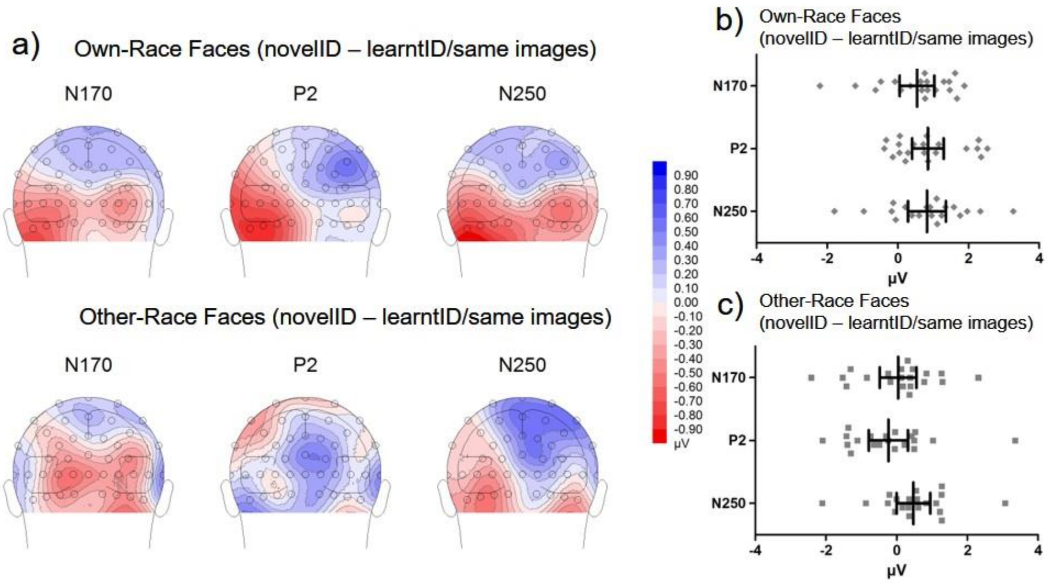

Figure 5.4 Voltage maps and ERP learning effects. a) Voltage maps showing the scalp distribution of learning effects (novel ID – learnt ID/same images) for own- and other-race faces in N170, P2, and N250. b and c) Mean learning effects for own- and other-race faces. Error bars denote 95% confidence intervals, grey squares indicate individual subjects' data.

N170

A repeated measures ANOVA with the within-subjects factors hemisphere (left, right), site (TP, P), ethnicity (own-race, other-race) and ID type (learnt ID/same images, learnt ID/different images, novel ID) on N170 mean amplitude revealed a significant ethnicity x hemisphere x ID type interaction, $F(2,38) = 5.51$, $p = .008$, $\eta_p^2 = .225$, 90% CI [0.04, 0.37]. Follow-up analyses yielded a significant effect of ID type for own-race identities in the left hemisphere, $F(2,38) = 8.48$, $p = .001$, $\eta_p^2 = .309$, 90% CI [0.10, 0.45], indicating significantly more negative amplitudes for learnt ID/same images relative to novel ID, $F(1,19) = 5.39$, $p = .032$, $\eta_p^2 = .221$, 90% CI [0.01, 0.44]. A trend towards more negative amplitudes for learnt ID/different images as compared to novel ID was observed, $F(1,19) = 3.99$, $p = .060$, $\eta_p^2 = .174$, 90% CI [0.00, 0.40]. The effect of ID type for own-race identities at right-hemispheric electrodes and for other-race identities in both hemispheres failed to reach significance, all Fs ≤ 2.24, ps $\geq .121$, η_p^2s $\leq .105$. Additional follow-up analyses of the above three-way interaction were conducted to test for potential differences between own- and other-race faces. Post-hoc analyses did not yield any significant effects of ethnicity, all Fs$(1,19) \leq 1.76$, ps $\geq .201$, η_p^2s $\leq .085$.

P2

A corresponding ANOVA on P2 mean amplitude showed a significant ethnicity x ID type interaction, $F(2,38) = 4.62$, $p = .016$, $\eta_p^2 = .196$, 90% CI [0.02, 0.34], which further interacted with hemisphere, $F(2,38) = 5.41$, $p = .009$, $\eta_p^2 = .222$, 90% CI [0.04, 0.37]. Follow-up tests showed a significant effect of ID type for own-race identities at left-hemispheric electrodes, $F(2,38) = 11.11$, $p = .001$, $\eta_p^2 = .369$, 90% CI [0.15, 0.51], indicative of significantly more positive amplitudes for novel ID compared to learnt ID/same images, $F(1,19) = 15.95$, $p = .001$, $\eta_p^2 = .456$, 90% CI [0.16, 0.62], but comparable amplitudes for learnt ID/different images and novel ID, $F(1,19) = 1.79$, $p = .196$, $\eta_p^2 = .086$, 90% CI [0.00, 0.30]. A comparable effect of stimulus type was not observed for own-race identities at right-hemispheric electrodes, and was absent for other-race identities in both hemispheres, all Fs$(1,19)$ ≤ 1.28, ps $\geq .285$, η_p^2s $\leq .063$. Post-hoc analyses of this three-way interaction to test for potential effects of ethnicity revealed a significant effect of ethnicity for the learnt ID/same image condition in the left hemisphere, $F(1,19) = 9.79$, $p = .006$, η_p^2 $= .340$, 90% CI [0.07, 0.54], indicating more positive amplitudes for other- compared to own-race identities. No further significant effects of ethnicity were observed, all Fs$(1,19) \leq 3.19$, ps $\geq .090$, η_p^2s $\leq .144$.

N250

Analysis of the N250 time window yielded a significant ethnicity x site interaction, $F(1,19) = 4.55$, $p = .046$, $\eta_p^2 = .193$, 90% CI [0.01, 0.41], indicating significantly more negative amplitudes for other- compared to own-race identities at P9/10, $F(1,19) = 5.63$, $p = .028$, $\eta_p^2 = .228$, 90% CI [0.01, 0.45]. No comparable difference was observed at TP9/10, $F(1,19) = 0.162$, $p = .692$, $\eta_p^2 = .008$, 90% CI [0.00, 0.16].

In addition, a significant main effect of ID type was observed, $F(2,38) = 5.70$, $p = .007$, $\eta_p^2 = .231$, 90% CI [0.04, 0.38]. Post-hoc contrasts showed significantly more negative amplitudes for learnt ID/same images relative to novel ID, $F(1,19) = 6.52$, $p = .006$, $\eta_p^2 = .334$, 90% CI [0.07, 0.53], but no significant difference between learnt ID/different images and novel ID, $F(1,19) = 0.02$, $p = .890$, $\eta_p^2 = .001$, 90% CI [0.00, 0.04]. The ethnicity x ID type interaction did not reach significance, $F(2,38) = 0.975$, $p = .387$, $\eta_p^2 = .049$, 90% CI [0.00, 0.16].

5.4 Discussion

The aim of the present study was to investigate the neural correlates of own- and other-race face identity learning. Caucasian participants first sorted ambient images of two own- and other-race faces into separate clusters for each identity and were further familiarised with these identities during a matching task. In line with our hypotheses, we observed better sorting of own- compared to other-race faces. Moreover, as predicted, participants were more accurate at matching own- relative to other-race identities, and an improvement in matching accuracy across blocks was evident for own-race identities only. Moreover, we compared ERPs for previously seen und unseen images of the learnt identities with those for images of novel identities. Starting in the N170 time range, more negative amplitudes were observed for learnt ID/same images compared to novel ID images. However, this ERP learning effect was only obtained for own-race identities. Within the N250 time range, increased amplitudes for learnt ID/same images relative to novel ID images were observed, and this effect was not further modulated by ethnicity. These findings are discussed in more detail below.

In line with previous work, we observed better sorting and matching for own- than for other-race faces (e.g., Laurence et al., 2016; Yan et al., 2016), suggesting that recognising an unfamiliar face from different images is even more challenging for faces from a different ethnic group. The present results extend previous findings to the variant of the sorting task in which participants are informed about the correct number of identities in the set. In addition, during matching, participants further became increasingly familiar with own-race identities, which was evident from a gradual gain in accuracy across blocks 1 to 3, while no improvement was detected for other-race identities. These findings suggest an own-race advantage in identity learning from multiple, highly variable images (see also Hayward et al., 2017; Zhou et al., 2018).

Regarding our ERP results, we observed clearly more pronounced learning effects for own- compared to other-race identities in two relatively early time windows. Within the N170 time range, more negative amplitudes for learnt ID/same images relative to the novel ID condition were obtained for own-race but not for other-race identities. Similarly, P2 was more positive in the novel ID condition compared to learnt ID/same images of own-race identities, while a comparable effect was absent for other-race identities. While N170 has often been reported to be insensitive to familiarity (e.g., Bentin & Deouell, 2000; Schweinberger & Burton, 2003; Zimmermann & Eimer, 2013; 2014), others have observed familiarity effects within the N170 time range, e.g. for personally familiar faces (Caharel, Jacques, d'Arripe, Ramon, & Rossion, 2011; Caharel et al., 2002; but see Keyes, Brady, Reilly, & Foxe, 2010; Wiese et al., in press). However, previous studies investigating face learning usually did not find familiarity effects in N170 (Andrews et al., 2017; Kaufmann et al., 2009; but see Scott, Tanaka, Sheinberg, & Curran, 2006 for increased N170 following training with multiple exemplars of non-face objects). Importantly, N170 familiarity effects observed in previous studies typically reflect the repeated presentation of a specific image (Caharel, Courtay, Bernard, Lalonde, & Rebai, 2005), or generalise across relatively small changes in viewpoint (Caharel et al., 2011). Similarly, ERP learning effects in the present study likely represent image repetition to some extent. Our results are therefore in line with the suggestion that familiarity or learning effects prior to N250 do not reflect image-independent face recognition.

At the same time, we suggest that the modulations of components prior to N250 in the present study to some extent reflect the facilitated processing of recently learnt own-race identities. On the one hand, the finding of more negative N170 and less positive P2 amplitudes for learnt ID/same images compared to novel ID images indeed more closely resembles image learning rather than image-independent face learning. Our ERP effects were observed after repeated presentation of a specific image set during learning (each image was presented 8 times during matching alone) and learning effects did not generalise to novel instances. Moreover, as noted above, it is known that N170 is affected by image repetition (Caharel et al., 2005). On the other hand, however, repetition alone cannot fully account for the present N170/P2 learning effects. First, results from the matching task indicate that participants were indeed able to recognise individual identity for own-race faces presented during learning, at least within the set presented during matching. Second, and more importantly, if these ERP effects only reflected image repetition, a similar effect should have also been obtained for other-race faces. Yet, N170 learning effects were clearly absent for other-race identities.

However, it is not entirely clear why none of the ERP learning effects, including those observed in the N250, generalised to a new set of images. This result is clearly at variance with previous studies (Andrews et al., 2017). The discrepancy to previous work might be related to the extensive training with a specific subset of images in the present study. More specifically, the repeated presentation of images from the sorting task during matching may have resulted in the integration of these images into novel representations. It appears plausible that direct links between the specific images of a given identity were formed during matching, while more abstract representations, e.g., containing information about possible within-person variability, were not established. In other words, our procedure might have strongly tied newly-learnt representations to the particular image set, which made the later integration of novel pictures more difficult. Therefore, the lack of image-independent ERP learning effects in the present study seems to suggest that the perceptual representations formed for the recently learnt identities only include those specific images that were repeatedly presented during sorting and matching. However, as they allow recognition of identity over a range of different images, such representations may reflect a first step towards complete image-independent face recognition. Crucially, such representations also appear to be much harder to establish for other-race faces.

Of note, a further important difference between the present study and Andrews et al. (2017) lies in the number of to-be-learnt identities. In Andrews et al. (2017), participants were required to learn two identities, whereas in the present study, participants had to learn two own- as well as two other-race identities. Learning twice as many identities may have increased memory load in the present study, and might have affected our results in particular in the second learning block. Future research may investigate whether increasing memory load indeed impairs identity learning.

Interestingly, although learning effects within N170 and P2 were limited to own-race identities, we did not find main effects of ethnicity within these time windows (see Table 5.1). As detailed in the introduction, N170 is often found to be more negative for other- relative to own-race faces (e.g., Cassidy et al., 2014; Wiese et al., 2014), although others did not find respective effects (e.g., Herzmann et al., 2011; Wiese et al., 2009). Previous attempts to reconcile such findings have focused on differential task demands, with ethnicity effects unlikely to emerge when identity is not task-relevant (Wiese, 2013). The present results further support this suggestion as in the present study N170 ethnicity effects were absent in a task that required participants to respond to infrequently occurring butterflies. Ethnicity effects in the present study first emerged in the N250 time range. In line with previous findings (Herzmann et al., 2011; Stahl et al., 2010, Wiese & Schweinberger, 2018), we observed more negative N250 amplitudes for other- compared to own-race faces, which has been suggested to reflect more effortful processing (Herzmann, 2016).

As discussed in the introduction, the ORB is usually taken to result from either differences in perceptual expertise (e.g., Michel, Rossion, Han, Chung, & Caldara, 2006; Rhodes et al., 2009; Valentine & Endo, 1992; Valentine, Lewis, &

Hills, 2016) or socio-cognitive factors, such as early categorisation of faces into social in- and out-groups (e.g., Hugenberg, Young, Bernstein, & Sacco, 2010; Levin, 1996, 2000; Sporer, 2001). Difficulties in learning other-race facial identities have typically been interpreted to reflect reduced perceptual expertise with the other-race face category (e.g., Proietti et al., 2018; Zhou et al., 2018), as identity learning tasks strongly emphasise processing of individuating information for both own- and other-race faces. The results of the present study confirm previous findings from behavioural studies, which observed advantages for own-race face identity learning. Moreover, our ERP results suggest that such learning advantages manifest at an early perceptual level, which is in line with expertise accounts.

A potential limitation of the present study is that only Caucasian participants were tested. It is therefore in principle possible that the East Asian face identities were simply more difficult to learn, independent of their ethnic in- or out-group status. If this were the case, East Asian participants should show similar difficulties of learning the specific East Asian face identities used in the present study. However, in a recently conducted behavioural study (Tüttenberg & Wiese, in revision), we tested both Caucasian and East Asian participants living in the UK with the same stimulus set. We observed clearly different learning patterns in the two participant groups. While Caucasian participants showed a clear advantage for own-race facial identities, East Asian participants learnt both own- and other-race identities similarly well. This was interpreted to reflect East Asian participants' increased experience with other-race Caucasian faces. Therefore, while we cannot fully exclude the possibility that some differences with respect to difficulty exist between the sets, we are confident that these play at best a minor role.

In conclusion, we observed a clear advantage for own-race face identity learning, which presumably reflects reduced perceptual expertise with other-race faces. For the first time, we showed a similar benefit for own- relative to other-race face learning in ERPs. We observed face learning effects in two components, N170 and P2. These effects were limited to own-race identities, and suggest an advantage for processing own-race identities at an early perceptual level. Later neural correlates of identity learning were not statistically different for own- and other-race identities. Overall, given the clear emphasis in the present study to represent all face identities at an individual level, our finding of clear learning advantages for own-race faces is well in line with perceptual expertise accounts of the own-race bias

6 General Discussion

The overall aim of this thesis was to investigate the role of perceptual expertise and socio-cognitive factors for the ORB. This was achieved by examining ethnicity-related differences in face memory, with different experimental paradigms and using both behavioural and event-related brain potential measures.

6.1 Summary of experimental work

The first part of this thesis (Chapters 2 and 3) examined whether increasing motivation to individuate can attenuate or even eliminate the ORB. The experiments reported in Chapter 2 investigated whether own- and other-race faces are similarly affected by a modulation of the intention to remember or forget. Therefore, item-method directed forgetting (DF, Bjork, 1970) was applied while participants learned own- and other-race as well as other social in- and out-group faces (based on minimal-group paradigms and the own-gender bias). If the ORB resulted from reduced perceptual expertise with other-race faces, DF for own- but not other-race faces would be expected, as participants without specific expertise would not be able to encode other-race faces in sufficient detail, independent of their motivation to individuate. In contrast, comparable DF for own- and other-race faces would be predicted if the ORB was driven by socio-cognitive factors. In line with an expertise account, the results revealed DF for own- but not other-race faces in Caucasian participants with limited other-race contact (Experiments 1 and 5), while East Asian participants who had substantial contact with other-race faces demonstrated similar DF for own- and other-race faces (Experiment 2). In addition, Caucasian participants showed clear DF for faces belonging to other social in- and out-groups (Experiments

3 and 4), which arguably do not differ substantially with respect to perceptual expertise. Together, these experiments indicate that motivation alone cannot fully explain the ORB. Rather, these findings suggest than an intentional modulation of face memory is possible, but restricted to those face categories participants have acquired substantial expertise with.

The experiment reported in Chapter 3 investigated whether the ORB can be reduced when participants are informed about the ORB and instructed to pay particular attention to other-race faces during learning prior to taking part in a recognition memory experiment (Hugenberg, Miller, & Claypool, 2007). Here, to complement previous work on this topic, a particular interest was to investigate whether these individuating instructions modulate neural correlates of successful learning, so-called ERP Dm effects. Individuating instructions reduced the ORB in recognition memory, which was particularly evident in hit rates. At the same time, a clear ORB was evident in the signal detection measure of sensitivity, *d*', even in the instruction condition. These findings suggest that increased attention to other-race faces during learning can improve recognition to some extent, which is line with a socio-cognitive account of the ORB (e.g., Hugenberg, Young, Bernstein, & Sacco, 2010). At the same time, individuating instructions also significantly increased ERP Dm effects for other-race faces, indicating that additional effort was required to reduce the difficulties associated with other-race face recognition. Thus, the present results show that although other-race face recognition can, to some extent, be improved by motivational factors, additional resources are required to partly compensate for reduced experience with other-race faces.

The second part of this thesis (Chapters 4 and 5) investigated learning of own- and other-race facial identities. Participants first learned own- and other-race faces from ambient images in the context of an implicit learning task. Subsequently, identity learning was assessed by examining whether previous exposure to facial identities generalised to previously unseen images of these identities. Previous work suggests that these learning paradigms encourage individuation of both own- and other-race identities, and thus, any potential advantage for own- relative to other-race faces likely reflects differences in perceptual expertise rather than socio-cognitive or motivational factors (e.g., Hayward, Favelle, Oxner, Chu, & Lam, 2017; Zhou, Matthews, Baker, & Mondloch, 2018). In Chapter 4, participants initially learned own- and other-race faces while sorting images of own- and other-race faces into separate identity clusters and were subsequently required to either match previously unseen images of learnt and unfamiliar identities for identity (Experiment 1) or make old/new decisions for these images (Experiment 2). While Caucasian participants revealed a clear own-race advantage in sorting, matching and old/new recognition, a corresponding own-race advantage was not detected in East Asian participants with substantial other-race contact. Unexpectedly, this participant group even showed better learning for other- relative to own-race faces in the context of a matching task, which was interpreted to result from their increased motivation to individuate other-race faces. Thus, as predicted by a perceptual expertise account of the ORB, these experiments suggest that face identity learning is more difficult for other- relative to own-race faces, but these difficulties can be overcome by extensive experience with other-race faces. In fact, it seems that increased motivation may sometimes even facilitate other-race relative to own-race face identity learning when participants have acquired substantial other-race expertise, which supports recent suggestions that perceptual expertise and socio-cognitive factors may interact (Wan, Crookes, Reynolds, Irons, & McKone, 2015).

In a further step, Chapter 5 investigated the neural correlates underlying identity learning of own- and other-race faces. After completing the same sorting task as in Chapter 4, Caucasian participants were further familiarised with these identities during a matching task. As in Chapter 4, participants sorted own-race identities more accurately than other-race identities. In addition, matching accuracy for own-race identities increased across blocks whereas performance did not improve for other-race identities. Subsequently, relative to other-race identities, learnt own-race identities elicited more negative N170 and more positive P2 components than previously unseen identities. However, a corresponding effect was absent for other-race faces. This suggests that learnt own- but not other-race identities were processed more efficiently at a perceptual level. The subsequent N250, an ERP component sensitive to face learning, was more negative for learnt when compared to novel faces, irrespective of ethnicity. However, N250 was also generally more negative for other- relative to own-race faces. These results suggest that other-race facial identities were generally more difficult to process. Moreover, the results from this experiment are in line with those obtained for Caucasian participants in Chapter 4, and lend further support to a perceptual expertise account of the ORB.

6.2 How do the present findings relate to and extend previous work?

6.2.1 Perceptual expertise and socio-cognitive theories of the ORB

The experiments reported in this thesis generally support a perceptual expertise account of the ORB. Caucasian participants with limited other-race contact in Chapters 2, 4 and 5, as well as in the no instruction condition in Chapter 3, showed a clear ORB. At the same time, East Asian participants living in the UK showed comparable performance for own- and other-race faces in Chapters 2 and 4. The direct comparison of two groups of participants which differed with respect to the amount of contact and experience with people from the respective other-race category in Chapters 2 and 4 thus supports previous work showing that extensive contact with other-race people can attenuate the ORB (e.g., Hancock & Rhodes, 2008, Wiese, Kaufmann, & Schweinberger, 2014; Zhao, Hayward, & Bülthoff, 2014). Interestingly, the comparison of two groups of participants in the present thesis strongly suggests that extensive experience with other-race faces can not only reduce but completely *eliminate* any disadvantage for recognising other-race faces. It needs to be acknowledged, however, that the participant groups were not fully balanced with regard to contact (i.e., Caucasian participants with high amounts of other-race contact and East Asian participants with limited other-race contact were not tested), which leaves the possibility that some of the observed effects were related to differences between participant groups that are unrelated to perceptual expertise.

Similarly, ERP results from Chapter 5 also support a perceptual expertise account of the ORB. In particular, N170 was more negative, and P2 less positive for learnt identities relative to novel identities, and no comparable effects were observed for other-race identities. These results thus suggest a clear processing advantage for learnt own-race faces in Caucasian participants at an early perceptual level, which is in line with perceptual expertise accounts (e.g., Michel, Rossion, Han, Chung, & Caldara, 2006; Mondloch et al., 2010; Valentine, 1992; Valentine, Lewis, & Hills, 2016). At the same time, learning effects within the N250 time range were unaffected by ethnicity. However, N250 was also generally more negative for other-race identities, which has been suggested to reflect more effortful processing of other-race faces (Herzmann, 2016). The results from Chapter 5 thus extend the results from Chapter 4 and show similar advantages for own-race face learning in ERPs, which likely result from reduced perceptual expertise with other-race faces.

In addition, the present results offer novel insights into how perceptual expertise and socio-cognitive or motivational factors interact. First, Chapter 2 revealed DF for both own- and other-race faces in East Asian participants, which has been interpreted to indicate that a modulation of face memory is possible provided that sufficient expertise for this face category has been acquired. Second, in Chapter 4 (Experiment 1), East Asian participants unexpectedly demonstrated significantly larger learning effects for other-race faces, which were interpreted to result from increased motivation to individuate other-race faces. Although these effects may, as discussed in more detail in Chapter 4, be task-specific and more research is clearly needed to provide further evidence for this suggestion, they are in line with recent accounts that perceptual expertise and socio-cognitive factors can interact (Wan et al., 2015).

Crucially, however, the present results are somewhat hard to integrate with previous suggestions on how exactly this interaction emerges. For instance, whereas the CIM (Hugenberg, et al., 2010) proposes that perceptual expertise only becomes fully effective when participants are sufficiently motivated to individuate other-race faces, the results from the present thesis, and in particular Chapters 2 and 4, suggest that a modulation of face memory by motivational factors is only possible for those faces we have acquired substantial expertise with. It thus appears that CIM places relatively more emphasis on motivation than expertise, while the present results suggest the opposite pattern. However, as discussed in more detail in Chapter 1, it has recently been proposed that the relative contribution of these two factors can vary depending on the cultural setting in which the ORB is investigated (Wan et al., 2015). The present results therefore do not contradict the CIM, which is mostly derived from US American research, but further emphasise the limitations of its generalisability to other cultural settings.

Interestingly, Chapter 3 revealed that individuating instructions reduced the ORB in recognition memory. Such a finding is generally in line with socio-cognitive accounts of the ORB, which suggests that reduced recognition of other-race faces results from a lack of attention to other-race faces during learning (e.g., Hugenberg et al., 2010). At the same time, a clear ORB was observed in the sensitivity measure *d*', suggesting that an individuation instruction is not sufficient to *eliminate* the effect if participants do not have extensive other-race expertise. However, this pattern of similar performance for own- and other-race faces was repeatedly observed in East Asian participants with extensive other-race experience (see Chapters 2 and 4). Moreover, ERP results in Chapter 3 revealed that enhanced learning of other-race faces required additional effort, which again indicates that factors other than motivation likely also contributed to the ORB in this experiment.

In sum, the findings from the present thesis suggest that the ORB is primarily driven by perceptual expertise if participants have no extensive experience with other-race faces. In this situation, motivational factors can modulate the effect only to some extent. However, given that participants have acquired substantial experience with other-race people, a combination of enhanced perceptual expertise and motivation to individuate can fully eliminate (or even reverse) the ORB. Therefore, the present results suggest that both expertise and motivation to individuate affect the ORB, but that expertise is the relatively more important factor.

6.2.2 Differences between own- and other-race faces were evident in different paradigms and measures

In addition to the above discussed interplay between perceptual expertise and socio-cognitive or motivational factors, the experiments reported in this thesis further emphasise that the ORB is a robust phenomenon. More specifically, difficulties with other-race faces were observed in Caucasian participants who had limited expertise with East Asian faces across a number of different tasks and measures.

First, an ORB was observed in the classic old/new recognition memory paradigm (Chapter 3, no instruction group). This paradigm was used in the very first demonstration of the phenomenon (Malpass & Kravitz, 1969) and has been replicated many times since. Better recognition of own- relative to other-race faces was evident in different performance measures, such as hits, correct rejections, and the sensitivity measure *d*'. Similarly, an ORB was also observed in a variant of this paradigm, the directed forgetting procedure (Bjork, 1970, Chapter 2, Experiments 1 and 5). The systematic application of directed forgetting to the study of the ORB is novel and, as discussed above, resulted in a number of relevant additions to our understanding of the phenomenon. Second, difficulties with other-race faces were present in identity learning paradigms. Here, Caucasian participants were better at sorting multiple ambient images of own- relative to other-race identities into separate identity clusters (Chapters 4 and 5). These initial difficulties observed during learning other-race identities also propagated to subsequent tasks when participants had to match previously unseen images of the learnt identities for identity or make old/new decisions for these images (Chapter 4). Similarly, in Chapter 5, a behavioural learning advantage during matching was only observed for own-race faces, and ERP results suggested a clear processing advantage for own-race faces at an early perceptual level.

Thus, Caucasian participants consistently showed better performance for own- relative to other-race faces in various different tasks. Whereas difficulties with other-race faces in old/new recognition memory paradigms are well-established, the investigation of differences between own- and other-race faces in identity learning paradigms has only recently received attention from researchers. As discussed in the Introduction and Chapters 4 and 5, identity learning paradigms require participants to attend to identity cues, e.g., when multiple ambient images of two different people have to be sorted into separate identity clusters, and such tasks may arguably more strongly emphasise individuation of own- and other-race faces compared to the learning phase of an old/new recognition memory paradigm (but note individuating instructions that explicitly instruct participants to attend to individuating features in other-race faces). Yet, better performance with own- compared to other-race faces was observed with both old/new recognition memory and identity learning paradigms. Thus, participants who have had only limited contact with people from the respective other-race group struggled with faces from categories they are less familiar with, and this was observed regardless of whether the paradigms specifically encouraged individuation of the identities or not.

At the same time, East Asian participants showed comparable performance with faces from both ethnic categories (for a notable exception of more pronounced learning effects for *other*-race faces, see Chapter 4, Experiment 1), and this too was evident in old/new recognition memory and identity learning paradigms. Thus, the fact that for each participant group, a specific pattern of results was consistently observed across tasks appears to suggest that ethnicity-related effects in face memory are highly robust and can, at least within the scope of the present thesis, be observed irrespective of a specific paradigm.

In sum, the results from this thesis suggest that the ORB primarily reflects differential perceptual expertise with faces from different ethnic groups, which can consistently be observed with different paradigms and measures. In line with this interpretation, a complete elimination of the effect is only observed when substantial long-term expertise for the other-race face category has been acquired. When extensive expertise with other-race faces is lacking, explicit instructions to attend to other-race faces during learning can only reduce difficulties recognising other-race faces to some extent.

6.2.3 What do the present results suggest for applied settings?

As noted at various points throughout this thesis, the failure to correctly recognise a person can potentially have severe consequences. Previous research suggests that it is difficult to recognise an unfamiliar person in different pictures (e.g., Bruce et al., 1999; Jenkins, White, Van Montfort, & Burton, 2011). Yet this is a task that is often required in applied settings (for a more detailed discussion, see Bruce, 2011). For example, eyewitnesses may be required to identify a criminal from a line-up or from pictures in a database. In addition, police and passport officers have to verify whether photo ID presented by an individual indeed shows this person.

In line with previous work, the results from this thesis clearly highlight how difficult it can be to recognise an unfamiliar person in different images. Moreover, the present results suggest that this may be even harder for unfamiliar other-race faces. At the same time, the results from this thesis suggest that this additional difficulty associated with the recognition of unfamiliar other-race faces can be overcome by extensive experience with faces from different ethnic groups. Increasing motivation to individuate in participants lacking sufficient perceptual expertise seems to be only moderately helpful. However, while, as demonstrated in Chapter 4 (Experiment 1), increased motivation to individuate might sometimes even result in overcompensating difficulties with other-race faces in participants with substantial relevant experience, it remains to be investigated whether this can also be observed in tasks that more closely resemble those required in applied settings.

The present experiments were designed to investigate the contribution of perceptual expertise and socio-cognitive factors for the ORB. In particular, Chapters 4 and 5 were aimed at examining own- and other-race face recognition in paradigms that more closely resemble the experience of getting to know someone in real life and results suggest that this is easier for faces of ethnic groups one has acquired substantial expertise with. More research is clearly needed to understand how faces become familiar, and perhaps this may also help understand how problems with unfamiliar face recognition can be mitigated in applied settings. Thus, while it seems fair to say that the present results underscore how difficult it can be to recognise unfamiliar, and particularly unfamiliar other-race people, more research is clearly needed to more fully understand the difficulties associated with unfamiliar face recognition and its implications for real-life applications.

6.3 Limitations and directions for future research

One limitation of the present thesis is that the experiments reported in Chapters 2 and 3 use a single picture for each identity, both during learning and at test. As discussed in more detail in Chapter 1, this might to some extent test image rather than face recognition (Burton, 2013). Outside the lab, however, faces might change substantially between encounters and any experiment that examines unfamiliar face recognition using a single image for each identity does not appropriately capture the challenges of recognising an unfamiliar face in real life. This not only limits the generalisability of results, but may ultimately also hinder any progress into understanding the differences between unfamiliar and familiar face recognition (see also Burton, 2013). Similarly, experimental approaches that rely on image rather than face recognition might not fully capture the problem of other-race face recognition in real life (Hayward et al., 2017). We need to understand how well people can recognise unfamiliar own- and other-race faces despite variation and this may advance our theoretical understanding of the ORB and perhaps offer important insights into how problems associated with unfamiliar as well as unfamiliar other-race faces can be mitigated in applied contexts such as passport control and eyewitness testimony.

A further limitation of the present experiments is that, as referred to above, participant groups were not fully balanced with regard to contact. In Chapters 2 and 4, Caucasian participants who had predominant contact with own-race people as well as East Asian participants who had extensive other-race contact due to living in the UK were tested. Whereas the former group consistently showed an ORB, a comparable bias was not detected in East Asian participants, which was interpreted to reflect their increased contact with Caucasian faces and the resulting expertise for this face category. However, this interpretation would be substantially strengthened if one were to show an own-race advantage in East Asian participants with little contact with Caucasian faces, and reduced or even absent own-race advantages in Caucasian participants living in East Asian countries. A further advantage of such fully balanced designs would be that they allow for a more direct examination into potential differences in general stimulus difficulty between the two stimulus sets.

These limitations may be addressed in future research. As discussed above, further work is clearly needed to understand own- and other-race face recognition under ecologically more valid conditions. In particular, future research may investigate whether a modulation of the motivation to individuate will differentially affect the recognition of own- and other-race faces from more variable and arguably ecologically more valid stimuli. Moreover, to further investigate the role of perceptual expertise and socio-cognitive or motivational mechanisms, it may be helpful to directly compare learning of own- and other-race faces with learning of faces from other social categories which arguably do not differ in terms of expertise, such as own- and other-gender faces.

Finally, the present experiments have shown that testing two groups of participants (Caucasian and East Asian) can shed light on the different contribution of perceptual expertise and socio-cognitive or motivational factors to the ORB and can help rule out differences in general stimulus difficulty between the two stimulus sets (but note limitations discussed above). Thus, although practical reasons sometimes make it hard to accomplish these fully balanced designs, future studies should, whenever possible, test participants from two ethnic groups and/or groups that vary with respect to expertise with other-race people as this may offer valuable insights into the mechanisms underlying the ORB.

7 References

Ackerman, J. M., Shapiro, J. R., Neuberg, S. L., Kenrick, D. T., Becker, D. V., Griskevicius, V., . . . Schaller, M. (2006). They all look the same to me (unless they're angry): From out-group homogeneity to out-group heterogeneity. *Psychological Science, 17*(10), 836-840. doi:10.1111/j.1467-9280.2006.01790.x

Anderson, M. C. (2005). The role of inhibitory control in forgetting unwanted memories: A consideration of three methods. *Dynamic Cognitive Processes*, 159-189. doi:10.1007/4-431-27431-6_8

Anderson, M. C., & Hanslmayr, S. (2014). Neural mechanisms of motivated forgetting. *Trends in Cognitive Sciences, 18*(6), 279-292. doi:10.1016/j.tics.2014.03.002

Andrews, S., Burton, A. M., Schweinberger, S. R., & Wiese, H. (2017). Event-related potentials reveal the development of stable face representations from natural variability. *Quarterly Journal of Experimental Psychology, 70*(8), 1620-1632. doi:10.1080/17470218.2016.1195851

Andrews, S., Jenkins, R., Cursiter, H., & Burton, A. M. (2015). Telling faces together: Learning new faces through exposure to multiple instances. *Quarterly Journal of Experimental Psychology, 68*(10), 2041-2050. doi:10.1080/17470218.2014.1003949

Anthony, T., Copper, C., & Mullen, B. (1992). Cross-racial facial identification: A social cognitive integration. *Personality and Social Psychology Bulletin, 18*(3), 296-301. doi:10.1177/0146167292183005

Baker, K. A., Laurence, S., & Mondloch, C. J. (2017). How does a newly encountered face become familiar? The effect of within-person variability on adults' and children's perception of identity. *Cognition, 161*, 19-30. doi:10.1016/j.cognition.2016.12.012

Balas, B., & Nelson, C. A. (2010). The role of face shape and pigmentation in other-race face perception: An electrophysiological study. *Neuropsychologia, 48*(2), 498-506. doi:10.1016/j.neuropsychologia.2009.10.007

Basden, B. H., & Basden, D. R. (1996). Directed forgetting: Further comparisons of the item and list methods. *Memory, 4*(6), 633-653. doi:10.1080/741941000

Basden, B. H., Basden, D. R., & Gargano, G. J. (1993). Directed forgetting in implicit and explicit memory tests: A comparison of methods. *Journal of Experimental Psychology-Learning Memory and Cognition, 19*(3), 603-616. doi:10.1037//0278-7393.19.3.603

Begleiter, H., Porjesz, B., & Wang, W. Y. (1995). Event-related brain potentials differentiate priming and recognition to familiar and unfamiliar faces. *Electroencephalography and Clinical Neurophysiology, 94*(1), 41-49. doi:10.1016/0013-4694(94)00240-l

Benson, P. J., & Perrett, D. I. (1994). Visual processing of facial distinctiveness. *Perception, 23*(1), 75-93. doi:10.1068/p230075

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8*(6), 551-565. doi:10.1162/jocn.1996.8.6.551

Bentin, S., & Deouell, L. Y. (2000). Structural encoding and identification in face processing: ERP evidence for separate mechanisms. *Cognitive Neuropsychology, 17*(1-3), 35-54. doi:10.1080/026432900380472

Bernstein, M. J., Young, S. G., & Hugenberg, K. (2007). The cross-category effect: Mere social categorization is sufficient to elicit an own-group bias in face recognition. *Psychological Science, 18*(8), 706-712. doi:10.1111/j.1467-9280.2007.01964.x

Bindemann, M., Avetisyan, M., & Blackwell, K. A. (2010). Finding Needles in Haystacks: Identity Mismatch Frequency and Facial Identity Verification. *Journal of Experimental Psychology-Applied, 16*(4), 378-386. doi:10.1037/a0021893

Bindemann, M., Burton, A. M., Leuthold, H., & Schweinberger, S. R. (2008). Brain potential correlates of face recognition: Geometric distortions and the N250r brain response to stimulus repetitions. *Psychophysiology, 45*(4), 535-544. doi:10.1111/j.1469-8986.2008.00663.x

Bindemann, M., & Sandford, A. (2011). Me, myself, and I: Different recognition rates for three photo-IDs of the same person. *Perception, 40*(5), 625-627. doi:10.1068/p7008

Bjork, R. A. (1970). Positive forgetting: The noniterference of Items intentionally forgotten. *Journal of Verbal Learning and Verbal Behavior, 9*(3), 255-268. doi:10.1016/s0022-5371(70)80059-7

Bornstein, B. H., Laub, C. E., Meissner, C. A., & Susa, K. J. (2013). The Cross-Race Effect: Resistant to Instructions. *Journal of Criminology,* 1-6. doi:10.1155/2013/745836

Bothwell, R. K., Brigham, J. C., & Malpass, R. S. (1989). Cross-racial identification. *Personality and Social Psychology Bulletin, 15*(1), 19-25. doi:10.1177/0146167289151002

Bruce, V. (1994). Stability from variation: The case of face recognition - The M.D. Vernon memorial lecture. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 47*(1), 5-28. doi:10.1080/14640749408401141

Bruce, V. (2011). Applied Research in Face Processing. In: A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.). The Oxford Handbook of Face Perception (pp. 131-146). Oxford, UK: Oxford University Press. doi:10.1093/oxfordhb/9780199559053.013.0017

Bruce, V., Henderson, Z., Greenwood, K., Hancock, P. J. B., Burton, A. M., & Miller, P. (1999). Verification of face identities from images captured on video. *Journal of Experimental Psychology-Applied, 5*(4), 339-360. doi:10.1037//1076-898x.5.4.339

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77*, 305-327. doi:10.1111/j.2044-8295.1986.tb02199.x

Bukach, C. M., Cottle, J., Ubiwa, J., & Miller, J. (2012). Individuation experience predicts other-race effects in holistic processing for both Caucasian and Black participants. *Cognition, 123*(2), 319-324. doi:10.1016/j.cognition.2012.02.007

Burton, A. M. (2013). Why has research in face recognition progressed so slowly? The importance of variability. *Quarterly Journal of Experimental Psychology, 66*(8), 1467-1485. doi:10.1080/17470218.2013.800125

Burton, A. M., Jenkins, R., Hancock, P. J. B., & White, D. (2005). Robust representations for face recognition: The power of averages. *Cognitive Psychology, 51*(3), 256-284. doi:10.1016/j.cogpsych.2005.06.003

Burton, A. M., Jenkins, R., & Schweinberger, S. R. (2011). Mental representations of familiar faces. *British Journal of Psychology, 102*, 943-958. doi:10.1111/j.2044-8295.2011.02039.x

Burton, A. M., Kramer, R. S. S., Ritchie, K. L., & Jenkins, R. (2016). Identity From Variation: Representations of Faces Derived From Multiple Instances. *Cognitive Science, 40*(1), 202-223. doi:10.1111/cogs.12231

Burton, A. M., Schweinberger, S. R., Jenkins, R., & Kaufmann, J. M. (2015). Arguments Against a Configural Processing Account of Familiar Face Recognition. *Perspectives on Psychological Science, 10*(4), 482-496. doi:10.1177/1745691615583129

Burton, A. M., & Vokey, J. R. (1998). The face-space typicality paradox: Understanding the face-space metaphor. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 51*(3), 475-483. doi:10.1080/713755768

Burton, A. M., White, D., & McNeill, A. (2010). The Glasgow Face Matching Test. *Behavior Research Methods, 42*(1), 286-291. doi:10.3758/brm.42.1.286

Burton, A. M., Wilson, S., Cowan, M., & Bruce, V. (1999). Face recognition in poor-quality video: Evidence from security surveillance. *Psychological Science, 10*(3), 243-248. doi:10.1111/1467-9280.00144

Byatt, G., & Rhodes, G. (2004). Identification of own-race and other-race faces: Implications for the representation of race in face space. *Psychonomic Bulletin & Review, 11*(4), 735-741. doi:10.3758/bf03196628

Caharel, S., Collet, K., & Rossion, B. (2015). The early visual encoding of a face (N170) is viewpoint-dependent: A parametric ERP-adaptation study. *Biological Psychology, 106*, 18-27. doi:10.1016/j.biopsycho.2015.01.010

Caharel, S., Courtay, N., Bernard, C., Lalonde, R., & Rebai, M. (2005). Familiarity and emotional expression influence an early stage of face processing: An electrophysiological study. *Brain and Cognition, 59*(1), 96-100. doi:10.1016/j.bandc.2005.05.005

Caharel, S., d'Arripe, O., Ramon, M., Jacques, C., & Rossion, B. (2009). Early adaptation to repeated unfamiliar faces across viewpoint changes in the right hemisphere: Evidence from the N170 ERP component. *Neuropsychologia, 47*(3), 639-643. doi:10.1016/j.neuropsychologia.2008.11.016

Caharel, S., Jacques, C., d'Arripe, O., Ramon, M., & Rossion, B. (2011). Early electrophysiological correlates of adaptation to personally familiar and unfamiliar faces across viewpoint changes. *Brain Research, 1387*, 85-98. doi:10.1016/j.brainres.2011.02.070

Caharel, S., Montalan, B., Fromager, E., Bernard, C., Lalonde, R., & Mohamed, R. (2011). Other-race and inversion effects during the structural encoding stage of face processing in a race categorization task: An event-related brain potential study. *International Journal of Psychophysiology, 79*(2), 266-271. doi:10.1016/j.ijpsycho.2010.10.018

Caharel, S., Poiroux, S., Bernard, C., Thibaut, F., Lalonde, R., & Rebai, M. (2002). ERPs associated with familiarity and degree of familiarity during face recognition. *International Journal of Neuroscience, 112*(12), 1499-1512. doi:10.1080/00207450290158368

Caldara, R., & Abdi, H. (2006). Simulating the 'other-race' effect with autoassociative neural networks: further evidence in favor of the face-space model. *Perception, 35*(5), 659-670. doi:10.1068/p5360

Caldara, R., Rossion, B., Bovet, P., & Hauert, C. A. (2004). Event-related potentials and time course of the 'other-race' face classification advantage. *Neuroreport, 15*(5), 905-910. doi:10.1097/01.wnr.0000119729.93564.3e

Calder, A. J., Burton, A. M., Miller, P., Young, A. W., & Akamatsu, S. (2001). A principal component analysis of facial expressions. *Vision Research, 41*(9), 1179-1208. doi:10.1016/s0042-6989(01)00002-5

Cassidy, K. D., Boutsen, L., Humphreys, G. W., & Quinn, K. A. (2014). Ingroup categorization affects the structural encoding of other-race faces: Evidence from the N170 event-related potential. *Social Neuroscience, 9*(3), 235-248. doi:10.1080/17470919.2014.884981

Cassidy, K. D., Quinn, K. A., & Humphreys, G. W. (2011). The influence of ingroup/outgroup categorization on same- and other-race face processing: The moderating role of inter- versus intra-racial context. *Journal of Experimental Social Psychology, 47*(4), 811-817. doi:10.1016/j.jesp.2011.02.017

Cavazos, J. G., Noyes, E., & O'Toole, A. J. (2018). Learning context and the other-race effect: Strategies for improving face recognition. *Vision Research*. doi:10.1016/j.visres.2018.03.003

Chance, J. E., & Goldstein, A. G. (1996). The other-race effect and eyewitness identification. In S. L. Sporer, R. S. Malpass, & G. Koehnken (Eds.). *Psychological issues in eyewitness identification* (pp. 153-176). Hillsdale, NJ, USA: Lawrence Erlbaum Associates, Inc.

Chiroro, P., & Valentine, T. (1995). An Investigation of the Contact Hypothesis of the Own-race Bias in Face Recognition. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 48*(4), 879-894.

Chiroro, P. M., Tredoux, C. G., Radaelli, S., & Meissner, C. A. (2008). Recognizing faces across continents: The effect of within-race variations on the own-race bias in face recognition. *Psychonomic Bulletin & Review, 15*(6), 1089-1092. doi:10.3758/pbr.15.6.1089

Costa, P. T., & McCrea, R. R. (1992). *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI): Professional manual*. Odessa, FL: Psychological Assessment Resources.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*(6), 671-684. doi:10.1016/s0022-5371(72)80001-x

Crookes, K., Favelle, S., & Hayward, W. G. (2013). Holistic processing for other-race faces in Chinese participants occurs for upright but not inverted faces. *Frontiers in Psychology, 4*. doi:10.3389/fpsyg.2013.00029

Crookes, K., & Rhodes, G. (2017). Poor recognition of other-race faces cannot always be explained by a lack of effort. *Visual Cognition*. doi:10.1080/13506285.2017.1311974

Cumming, G. (2012). *Understanding the New Statistics. Effect Sizes, Confidence Intervals, and Meta-Analysis*. New York: Routledge.

Cumming, G., & Calin-Jageman, R. (2017). *Introduction to the New Statistics: Estimation, Open Science, and Beyond*. New York: Routledge.

de Heering, A., de Liedekerke, C., Deboni, M., & Rossion, B. (2010). The role of experience during childhood in shaping the other-race effect. *Developmental Science, 13*(1), 181-187. doi:10.1111/j.1467-7687.2009.00876.x

Eimer, M. (2000a). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology, 111*(4), 694-705. doi:10.1016/s1388-2457(99)00285-0

Eimer, M. (2000b). The face-specific N170 component reflects late stages in the structural encoding of faces. *Neuroreport, 11*(10), 2319-2324. doi:10.1097/00001756-200007140-00050

Eimer, M. (2011). The face-sensitivity of the N170 component. In: A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.). The Oxford Handbook of Face Perception (pp. 329-344). Oxford, UK: Oxford University Press. doi:10.1093/oxfordhb/9780199559053.013.0017

Etchells, D. B., Brooks, J. L., & Johnston, R. A. (2017). Evidence for view-invariant face recognition units in unfamiliar face learning. *Quarterly Journal of Experimental Psychology, 70*(5), 874-889. doi:10.1080/17470218.2016.1248453

Fawcett, J. M., & Taylor, T. L. (2008). Forgetting is effortful: Evidence from reaction time probes in an item-method directed forgetting task. *Memory & Cognition, 36*(6), 1168-1181. doi:10.3758/mc.36.6.1168

Feingold, G. A. (1914). The influence of environment on identification of persons and things. *Journal of the American Institute of Criminal Law and Criminology, 5*(1), 39-51. doi:10.2307/1133283

Fitzgerald, R. J., Price, H. L., & Oriet, C. (2013). Intentionally Forgetting Other-Race Faces: Costs and Benefits? *Journal of Experimental Psychology: Applied, 19*(2), 130-142. doi:10.1037/a0033287

Friedman, D., & Johnson, R. (2000). Event-related potential (ERP) studies of memory encoding and retrieval: A selective review. *Microscopy Research and Technique, 51*(1), 6-28. doi:10.1002/1097-0029(20001001)51:1<6::aid-jemt2>3.3.co;2-i

Gajewski, P. D., Schlegel, K., & Stoerig, P. (2008). Effects of Human Race and Face Inversion on the N170 A Cross-Race Study. *Journal of Psychophysiology, 22*(4), 157-165. doi:10.1027/0269-8803.22.4.157

Ge, L. Z., Zhang, H. C., Wang, Z., Quinn, P. C., Pascalis, O., Kelly, D., . . . Lee, K. (2009). Two faces of the other-race effect: Recognition and categorisation of Caucasian and Chinese faces. *Perception, 38*(8), 1199-1210. doi:10.1068/p6136

Goernert, P. N., Corenblum, B., & Otani, H. (2011). Directed forgetting of faces: The role of response criterion. *Quarterly Journal of Experimental Psychology, 64*(10), 1930-1938. doi:10.1080/17470218.2011.595806

Golby, A. J., Gabrieli, J. D. E., Chiao, J. Y., & Eberhardt, J. L. (2001). Differential responses in the fusiform region to same-race and other-race faces. *Nature Neuroscience, 4*(8), 845-850. doi:10.1038/90565

Gosling, A., & Eimer, M. (2011). An event-related brain potential study of explicit face recognition. *Neuropsychologia, 49*(9), 2736-2745. doi:10.1016/j.neuropsychologia.2011.05.025

Gwinn, J. D., Barden, J., & Judd, C. M. (2015). Face recognition in the presence of angry expressions: A target-race effect rather than a cross-race effect. *Journal of Experimental Social Psychology, 58*, 1-10. doi:10.1016/j.jesp.2014.12.001

Hancock, K. J., & Rhodes, G. (2008). Contact, configural coding and the other-race effect in face recognition. *British Journal of Psychology, 99*, 45-56. doi:10.1348/000712607x199981

Hancock, P. J. B., Bruce, V., & Burton, A. M. (2000). Recognition of unfamiliar faces. *Trends in Cognitive Sciences, 4*(9), 330-337. doi:10.1016/s1364-6613(00)01519-9

Hauswald, A., & Kissler, J. (2008). Directed forgetting of complex pictures in an item method paradigm. *Memory, 16*(8), 797-809. doi:10.1080/09658210802169087

Hauswald, A., Schulz, H., Iordanov, T., & Kissler, J. (2011). ERP dynamics underlying successful directed forgetting of neutral but not negative pictures. *Social Cognitive and Affective Neuroscience, 6*(4), 450-459. doi:10.1093/scan/nsq061

Hayward, W. G., Crookes, K., Chu, M. H., Favelle, S. K., & Rhodes, G. (2016). Holistic Processing of Face Configurations and Components. *Journal of*

Experimental Psychology-Human Perception and Performance, 42(10), 1482-1488. doi:10.1037/xhp0000246

Hayward, W. G., Crookes, K., & Rhodes, G. (2013). The other-race effect: Holistic coding differences and beyond. *Visual Cognition*, *21*(9-10), 1224-1247. doi:10.1080/13506285.2013.824530

Hayward, W. G., Favelle, S. K., Oxner, M., Chu, M. H., & Lam, S. M. (2017). The other-race effect in face learning: Using naturalistic images to investigate face ethnicity effects in a learning paradigm. *Quarterly Journal of Experimental Psychology, 70*(5), 890-896. doi:10.1080/17470218.2016.1146781

Hayward, W. G., Rhodes, G., & Schwaninger, A. (2008). An own-race advantage for components as well as configurations in face recognition. *Cognition*, *106*(2), 1017-1027. doi:10.1016/j.cognition.2007.04.002

Hehman, E., Mania, E. W., & Gaertner, S. L. (2010). Where the division lies: Common ingroup identity moderates the cross-race facial-recognition effect. *Journal of Experimental Social Psychology*, *46*(2), 445-448. doi:10.1016/j.jesp.2009.11.008

Hehman, E., Stanley, E. M., Gaertner, S. L., & Simons, R. F. (2011). Multiple group membership influences face-recognition: Recall and neurological evidence. *Journal of Experimental Social Psychology*, *47*(6), 1262-1268. doi:10.1016/j.jesp.2011.05.014

Herlitz, A., & Loven, J. (2013). Sex differences and the own-gender bias in face recognition: A meta-analytic review. *Visual Cognition*, *21*, 1306-1336. doi: 10.1080/13506285.2013.823140

Herrmann, M. J., Schreppel, T., Jager, D., Koehler, S., Ehlis, A. C., & Fallgatter, A. J. (2007). The other-race effect for face perception: an event-related potential study. *Journal of Neural Transmission, 114*(7), 951-957. doi:10.1007/s00702-007-0624-9

Herzmann, G. (2016). Increased N250 amplitudes for other-race faces reflect more effortful processing at the individual level. *International Journal of Psychophysiology, 105*, 57-65. doi:10.1016/j.ijpsycho.2016.05.001

Herzmann, G., & Curran, T. (2013). Neural Correlates of the In-Group Memory Advantage on the Encoding and Recognition of Faces. *Plos One, 8*(12). doi:10.1371/journal.pone.0082797

Herzmann, G., Minor, G., & Adkins, M. (2017). Neural correlates of memory encoding and recognition for own-race and other-race faces in an associative-memory task. *Brain Research, 1655*, 194-203. doi:10.1016/j.brainres.2016.10.028

Herzmann, G., Minor, G., & Curran, T. (2018). Neural evidence for the contribution of holistic processing but not attention allocation to the other-race effect on face memory. *Cognitive Affective & Behavioral Neuroscience, 18*(5), 1015-1033. doi:10.3758/s13415-018-0619-z

Herzmann, G., Schweinberger, S. R., Sommer, W., & Jentzsch, I. (2004). What's special about personally familiar faces? A multimodal approach. *Psychophysiology, 41*(5), 688-701. doi:10.1111/j.1469-8986.2004.00196.x

Herzmann, G., Willenbockel, V., Tanaka, J. W., & Curran, T. (2011). The neural correlates of memory encoding and recognition for own-race and other-race faces. *Neuropsychologia, 49*(11), 3103-3115. doi:10.1016/j.neuropsychologia.2011.07.019

Hills, P. J., & Lewis, M. B. (2006). Reducing the own-race bias in face recognition by shifting attention. *Quarterly Journal of Experimental Psychology, 59*(6), 996-1002. doi:10.1080/17470210600654750

Hills, P. J., & Lewis, M. B. (2011). Reducing the own-race bias in face recognition by attentional shift using fixation crosses preceding the lower half of a face. *Visual Cognition, 19*(3), 313-339. doi:10.1080/13506285.2010.528250

Hole, G. J. (1994). Configural factors in the perception of unfamiliar faces. *Perception, 23*(1), 65-74. doi:10.1068/p230065

Hourihan, K. L., Fraundorf, S. H., & Benjamin, A. S. (2013). Same faces, different labels: Generating the cross-race effect in face memory with social category information. *Memory & Cognition, 41*(7), 1021-1031. doi:10.3758/s13421-013-0316-7

Hugenberg, K., & Corneille, O. (2009). Holistic Processing Is Tuned for In-Group Faces. *Cognitive Science, 33*(6), 1173-1181. doi:10.1111/j.1551-6709.2009.01048.x

Hugenberg, K., Miller, J., & Claypool, H. M. (2007). Categorization and individuation in the cross-race recognition deficit: Toward a solution to an insidious problem. *Journal of Experimental Social Psychology, 43*(2), 334-340. doi:10.1016/j.jesp.2006.02.010

Hugenberg, K., Wilson, J. P., See, P. E., & Young, S. G. (2013). Towards a synthetic model of own group biases in face memory. *Visual Cognition, 21*(9-10), 1392-1417. doi:10.1080/13506285.2013.821429

Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The Categorization-Individuation Model: An Integrative Account of the Other-Race Recognition Deficit. *Psychological Review, 117*(4), 1168-1187. doi:10.1037/a0020463

Ito, T. A., Thompson, E., & Cacioppo, J. T. (2004). Tracking the timecourse of social perception: The effects of racial cues on event-related brain potentials. *Personality and Social Psychology Bulletin, 30*(10), 1267-1280. doi:10.1177/0146167204264335

Jacques, C., & Rossion, B. (2007). Early electrophysiological responses to multiple face orientations correlate with individual discrimination performance in humans. *Neuroimage, 36*(3), 863-876. doi:10.1016/j.neuroimage.2007.04.016

Jenkins, R., & Burton, A. M. (2008). 100% accuracy in automatic face recognition. *Science, 319*(5862), 435-435. doi:10.1126/science.1149656

Jenkins, R., & Burton, A. M. (2011). Stable face representations. *Philosophical Transactions of the Royal Society B-Biological Sciences, 366*(1571), 1671-1683. doi:10.1098/rstb.2010.0379

Jenkins, R., White, D., Van Montfort, X., & Burton, A. M. (2011). Variability in photos of the same face. *Cognition, 121*(3), 313-323. doi:10.1016/j.cognition.2011.08.001

Johnston, R. A., & Edmonds, A. J. (2009). Familiar and unfamiliar face recognition: A review. *Memory, 17*(5), 577-596. doi:10.1080/09658210902976969

Kaufmann, J. M., & Schweinberger, S. R. (2012). The faces you remember: Caricaturing shape facilitates brain processes reflecting the acquisition of new face representations. *Biological Psychology, 89*(1), 21-33. doi:10.1016/j.biopsycho.2011.08.011

Kaufmann, J. M., Schweinberger, S. R., & Burton, A. M. (2009). N250 ERP Correlates of the Acquisition of Face Representations across Different Images. *Journal of Cognitive Neuroscience, 21*(4), 625-641. doi:10.1162/jocn.2009.21080

Kemp, R., Towell, N., & Pike, G. (1997). When seeing should not be believing: Photographs, credit cards and fraud. *Applied Cognitive Psychology*, *11*(3), 211-222.

Keyes, H., Brady, N., Reilly, R. B., & Foxe, J. J. (2010). My face or yours? Event-related potential correlates of self-face processing. *Brain and Cognition, 72*(2), 244-254. doi:10.1016/j.bandc.2009.09.006

Kloth, N., Shields, S. E., & Rhodes, G. (2014). On the Other Side of the Fence: Effects of Social Categorization and Spatial Grouping on Memory and Attention for Own-Race and Other-Race Faces. *Plos One*, *9*(9). doi:10.1371/journal.pone.0105979

Kokje, E., Bindemann, M., & Megreya, A. M. (2018). Cross-race correlations in the abilities to match unfamiliar faces. *Acta Psychologica, 185,* 13-21. doi:10.1016/j.actpsy.2018.01.006

Kramer, R. S. S., Jenkins, R., Young, A. W., & Burton, A. M. (2017). Natural variability is essential to learning new faces. *Visual Cognition, 25*(4-6), 470-476. doi:10.1080/13506285.2016.1242522

Kramer, R. S. S., Young, A. W., & Burton, A. M. (2018). Understanding face familiarity. *Cognition, 172*, 46-58. doi:10.1016/j.cognition.2017.12.005

Laurence, S., Zhou, X. M., & Mondloch, C. J. (2016). The flip side of the other-race coin: They all look different to me. *British Journal of Psychology, 107*(2), 374-388. doi:10.1111/bjop.12147

Lee, K., Byatt, G., & Rhodes, G. (2000). Caricature effects, distinctiveness, and identification: Testing the face-space framework. *Psychological Science, 11*(5), 379-385. doi:10.1111/1467-9280.00274

Lehman, E. B., McKinley-Pace, M., Leonard, A. M., Thompson, D., & Johns, K. (2001). Item-cued directed forgetting of related words and pictures in children and adults: Selective rehearsal versus cognitive inhibition. *Journal of General Psychology, 128*(1), 81-97. doi:10.1080/00221300109598900

Levin, D. T. (1996). Classifying faces by race: The structure of face categories. *Journal of Experimental Psychology-Learning Memory and Cognition, 22*(6), 1364-1382. doi:10.1037//0278-7393.22.6.1364

Levin, D. T. (2000). Race as a visual feature: Using visual search and perceptual discrimination tasks to understand face categories and the cross-race recognition. *Journal of Experimental Psychology-General, 129*(4), 559-574. doi:10.1037/0096-3445.129.4.559

Lewis, M. B., & Johnston, R. A. (1998). Understanding caricatures of faces. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 51*(2), 321-346. doi:10.1080/713755758

Liu, C. H., Chen, W. F., & Ward, J. (2015). Effects of exposure to facial expression variation in face learning and recognition. *Psychological Research-Psychologische Forschung, 79*(6), 1042-1053doi:10.1007/s00426-014-0627-8

Longmore, C. A., Liu, C. H., & Young, A. W. (2008). Learning faces from photographs. *Journal of Experimental Psychology-Human Perception and Performance, 34*(1), 77-100. doi:10.1037/0096-1523.34.1.77

Lucas, H. D., Chiao, J. Y., & Paller, K. A. (2011). Why some faces won't be remembered: brain potentials illuminate successful versus unsuccessful encoding for same-race and other-race faces. *Frontiers in Human Neuroscience, 5*. doi:10.3389/fnhum.2011.00020

Luck, S. J. (2014). *Introduction to the Event-Related Potential Technique, 2nd Edition*, pp. 1-406. Cambridge, MA, USA: MIT Press.

MacLeod, C. M. (1999). The item and list methods of directed forgetting: Test differences and the role of demand characteristics. *Psychonomic Bulletin & Review, 6*(1), 123-129. doi:10.3758/bf03210819

MacLin, O. H., & Malpass, R. S. (2001). Racial categorization of faces - The ambiguous race face effect. *Psychology Public Policy and Law, 7*(1), 98-118. doi:10.1037//1076-8971.7.1.98

MacLin, O. H., & Malpass, R. S. (2003). Last but not least - The ambiguous-race face illusion. *Perception, 32*(2), 249-252. doi:10.1068/p5046

Malpass, R. S., & Kravitz, J. (1969). Recognition for faces of own and other race. *Journal of Personality and Social Psychology, 13*(4), 330-334. doi:10.1037/h0028434

Matthews, C. M., & Mondloch, C. J. (2018). Improving Identity Matching of Newly Encountered Faces: Effects of Multi-image Training. *Journal of Applied Research in Memory and Cognition, 7*(2), 280-290. doi:10.1016/j.armac/2017.10.005

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6*(6), 255-260. doi:10.1016/s1364-6613(02)01903-4

Megreya, A. M., & Bindemann, M. (2009). Revisiting the processing of internal and external features of unfamiliar faces: The headscarf effect. *Perception, 38*(12), 1831-1848. doi:10.1068/p6385

Megreya, A. M., & Burton, A. M. (2006). Unfamiliar faces are not faces: Evidence from a matching task. *Memory & Cognition, 34*(4), 865-876. doi:10.3758/bf03193433

Megreya, A. M., & Burton, A. M. (2007). Hits and false positives in face matching: A familiarity-based dissociation. *Perception & Psychophysics, 69*(7), 1175-1184. doi:10.3758/bf03193954

Megreya, A. M., & Burton, A. M. (2008). Matching Faces to Photographs: Poor Performance in Eyewitness Memory (Without the Memory). *Journal of Experimental Psychology-Applied, 14*(4), 364-372. doi:10.1037/a0013464

Megreya, A. M., Sandford, A., & Burton, A. M. (2013). Matching Face Images Taken on the Same Day or Months Apart: the Limitations of Photo ID. *Applied Cognitive Psychology, 27*(6), 700-706. doi:10.1002/acp.2965

Megreya, A. M., White, D., & Burton, A. M. (2011). The other-race effect does not rely on memory: Evidence from a matching task. *Quarterly Journal of Experimental Psychology, 64*(8), 1473-1483. doi:10.1080/17470218.2011.575228

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology Public Policy and Law, 7*(1), 3-35. doi:10.1037/1076-8971.7.1.3

Meissner, C. A., Brigham, J. C., & Butz, D. A. (2005). Memory for own- and other-race faces: A dual-process approach. *Applied Cognitive Psychology, 19*(5), 545-567. doi:10.1002/acp.1097

Metzger, M. M. (2011). Directed Forgetting: Differential Effects on Typical and Distinctive Faces. *Journal of General Psychology, 138*(2), 155-168. doi:10.1080/00221309.2011.557407

Michel, C., Caldara, R., & Rossion, B. (2006). Same-race faces are perceived more holistically than other-race faces. *Visual Cognition, 14*(1), 55-73. doi:10.1080/13506280500158761

Michel, C., Corneille, O., & Rossion, B. (2007). Race categorization modulates holistic face encoding. *Cognitive Science, 31*(5), 911-924. doi:10.1080/03640210701530805

Michel, C., Corneille, O., & Rossion, B. (2010). Holistic face encoding is modulated by perceived face race: Evidence from perceptual adaptation. *Visual Cognition, 18*(3), 434-455. doi:10.1080/13506280902819697

Michel, C., Rossion, B., Han, J., Chung, C. S., & Caldara, R. (2006). Holistic processing is finely tuned for faces of one's own race. *Psychological Science, 17*(7), 608-615. doi:10.1111/j.1467-9280.2006.01752.x

Mondloch, C. J., Elms, N., Maurer, D., Rhodes, G., Hayward, W. G., Tanaka, J. W., & Zhou, G. M. (2010). Processes underlying the cross-race effect: An investigation of holistic, featural, and relational processing of own-race versus other-race faces. *Perception, 39*(8), 1065-1085. doi:10.1068/p6608

Murphy, J., Ipser, A., Gaigg, S. B., & Cook, R. (2015). Exemplar Variance Supports Robust Learning of Facial Identity. *Journal of Experimental Psychology-Human Perception and Performance, 41*(3), 577-581. doi:10.1037/xhp0000049

Nowicka, A., Jednorog, K., Wypych, M., & Marchewka, A. (2009). Reversed old/new effect for intentionally forgotten words: An ERP study of directed forgetting. *International Journal of Psychophysiology, 71*(2), 97-102. doi:10.1016/j.ijpsycho.2008.06.009

Noyes, E., & Jenkins, R. (2017). Improving Performance on a Difficult Face Matching Task. *Perception, 46*(2), 226-226.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9*(1), 97-113. doi:10.1016/0028-3932(71)90067-4

Paller, K. A., Bozic, V. S., Ranganath, C., Grabowecky, M., & Yamada, S. (1999). Brain waves following remembered faces index conscious recollection. *Cognitive Brain Research, 7*(4), 519-531. doi:10.1016/s0926-6410(98)00050-0

Paller, K. A., Kutas, M., & Mayes, A. R. (1987). Neural correlates of encoding in an incidental learning paradigm. *Electroencephalography and Clinical Neurophysiology, 67*(4), 360-371. doi:10.1016/0013-4694(87)90124-6

Papesh, M. H., & Goldinger, S. D. (2010). A multidimensional scaling analysis of own- and cross-race face spaces. *Cognition, 116*(2), 283-288. doi:10.1016/j.cognition.2010.05.001

Paz-Caballero, M. D., Menor, J., & Jimenez, J. M. (2004). Predictive validity of event-related potentials (ERPs) in relation to the directed forgetting effects. *Clinical Neurophysiology, 115*(2), 369-377. doi:10.1016/j.clinph.2003.09.011

Pica, E., Warren, A. R., Ross, D. F., & Kehn, A. (2015). Choosing Your Words and Pictures Wisely: When Do Individuation Instructions Reduce the Cross-Race Effect? *Applied Cognitive Psychology*, *29*(3), 360-368. doi:10.1002/acp.3112

Proietti, V., Laurence, S., Matthews, C. M., Zhou, X., & Mondloch, C. J. (2018). Attending to identity cues reduces the own-age but not the own-race recognition advantage. Vision Research. doi:10.1016/j.visres.2017.11.010

Quinlan, C. K., Taylor, T. L., & Fawcett, J. M. (2010). Directed Forgetting: Comparing Pictures and Words. *Canadian Journal of Experimental Psychology-Revue Canadienne De Psychologie Experimentale, 64*(1), 41-46. doi:10.1037/a0016569

Reber, P. J., Siwiec, R. M., Gitleman, D. R., Parrish, T. B., Mesulam, M. M., & Paller, K. A. (2002). Neural correlates of successful encoding identified using functional magnetic resonance imaging. *Journal of Neuroscience, 22*(21), 9541-9548.

Rezlescu, C., Susilo, T., Wilmer, J. B., & Caramazza, A. (2017). The Inversion, Part-Whole, and Composite Effects Reflect Distinct Perceptual Mechanisms With Varied Relationships to Face Recognition. *Journal of Experimental*

Psychology-Human Perception and Performance, 43(12), 1961-1973. doi:10.1037/xhp0000400

Rhodes, G., Brake, S., Taylor, K., & Tan, S. (1989). Expertise and configural coding in face recognition. *British Journal of Psychology, 80*, 313-331.

Rhodes, G., Ewing, L., Hayward, W. G., Maurer, D., Mondloch, C. J., & Tanaka, J. W. (2009). Contact and other-race effects in configural and component processing of faces. *British Journal of Psychology, 100*, 717-728. doi:10.1348/000712608x396503

Rhodes, G., Hayward, W. G., & Winkler, C. (2006). Expert face coding: Configural and component coding of own-race and other-race faces. *Psychonomic Bulletin & Review, 13*(3), 499-505. doi:10.3758/bf03193876

Rhodes, G., Locke, V., Ewing, L., & Evangelista, E. (2009). Race coding and the other-race effect in face recognition. *Perception, 38*(2), 232-241. doi:10.1068/p6110

Ritchie, K. L., & Burton, A. M. (2017). Learning faces from variability. *Quarterly Journal of Experimental Psychology, 70*(5), 897-905. doi:10.1080/17470218.2015.1136656

Ritchie, K. L., Kramer, R. S. S., & Burton, A. M. (2018). What makes a face photo a 'good likeness'? *Cognition, 170*, 1-8. doi:10.1016/j.cognition.2017.09.001

Ritchie, K. L., Smith, F. G., Jenkins, R., Bindemann, M., White, D., & Burton, A. M. (2015). Viewers base estimates of face matching accuracy on their own familiarity: Explaining the photo-ID paradox. *Cognition, 141*, 161-169. doi:10.1016/j.cognition.2015.05.002

Rodin, M. J. (1987). Who is memorable to whom: A study of cognitive disregard. *Social Cognition*, *5*(2), 144-165. doi:10.1521/soco.1987.5.2.144

Sadozai, A. K., Kempen, K., Tredoux, C., & Robbins, R. A. (2018). Can we look past people's race? The effect of combining race and a non-racial group affiliation on holistic processing. *Quarterly Journal of Experimental Psychology*. doi:10.1177/1747021818760482

Sangrigoli, S., & de Schonen, S. (2004). Effect of visual experience on face processing: a developmental study of inversion and non-native effects. *Developmental Science, 7*(1), 74-87. doi:10.1111/j.1467-7687.2004.00324.x

Sangrigoli, S., Pallier, C., Argenti, A. M., Ventureyra, V. A. G., & de Schonen, S. (2005). Reversibility of the other-race effect in face recognition during childhood. *Psychological Science, 16*(6), 440-444.

Schulz, C., Kaufmann, J. M., Kurt, A., & Schweinberger, S. R. (2012). Faces forming traces: Neurophysiological correlates of learning naturally distinctive and caricatured faces. *Neuroimage, 63*(1), 491-500. doi:10.1016/j.neuroimage.2012.06.080

Schweinberger, S. R., & Burton, A. M. (2003). Covert Recognition and the Neural System for Face Processing. *Cortex, 39*(1), 9-30. doi:10.1016/S0010-9452(08)70071-6

Schweinberger, S. R., Huddy, V., & Burton, A. M. (2004). N250r: a face-selective brain response to stimulus repetitions. *Neuroreport, 15*(9), 1501-1505. doi:10.1097/01.wnr.0000131675.00319.42

Schweinberger, S. R., & Neumann, M. F. (2016). Repetition effects in human ERPs to faces. *Cortex*, *80*, 141-153. doi:10.1016/j.cortex.2015.11.001

Schweinberger, S. R., Pfütze, E. M., & Sommer, W. (1995). Repetition priming and associative priming of face recognition: Evidence from event-related potentials. *Journal of Experimental Psychology-Learning Memory and Cognition, 21*(3), 722-736. doi:10.1037//0278-7393.21.3.722

Schweinberger, S. R., Pickering, E. C., Jentzsch, I., Burton, A. M., & Kaufmann, J. M. (2002). Event-related brain potential evidence for a response of inferior temporal cortex to familiar face repetitions. *Cognitive Brain Research, 14*(3), 398-409. doi:10.1016/s0926-6410(02)00142-8

Scott, L. S., Tanaka, J. W., Sheinberg, D. L., & Curran, T. (2006). A reevaluation of the electrophysiological correlates of expert object processing. *Journal of Cognitive Neuroscience, 18*(9), 1453-1465. doi:10.1162/jocn.2006.18.9.1453

Senholzi, K. B., & Ito, T. A. (2013). Structural face encoding: How task affects the N170's sensitivity to race. *Social Cognitive and Affective Neuroscience, 8*(8), 937-942. doi:10.1093/scan/nss091

Shapiro, P. N., & Penrod, S. (1986). Metaanalysis of facial identification studies. *Psychological Bulletin, 100*(2), 139-156. doi:10.1037//0033-2909.100.2.139

Short, L. A., & Mondloch, C. J. (2010). The importance of social factors is a matter of perception. *Perception, 39*(11), 1562-1564. doi:10.1068/p6758

Short, L. A., & Wagler, M. C. (2017). Social Categories Alone Are Insufficient to Elicit an In-Group Advantage in Perceptions of Within-Person Variability. *Perception, 46*(8), 929-940. doi:10.1177/0301006617699226

Shriver, E. R., & Hugenberg, K. (2010). Power, individuation, and the cross-race recognition deficit. *Journal of Experimental Social Psychology, 46*(5), 767-774. doi:10.1016/j.jesp.2010.03.014

Shriver, E. R., Young, S. G., Hugenberg, K., Bernstein, M. J., & Lanter, J. R. (2008). Class, race, and the face: Social context modulates the cross-race effect in face recognition. *Personality and Social Psychology Bulletin, 34*(2), 260-274. doi:10.1177/0146167207310455

Sommer, W., Heinz, A., Leuthold, H., Matt, J., & Schweinberger, S. R. (1995). Metamemory, disctinctiveness, and event-related potentials in recognition memory for faces. *Memory & Cognition*, *23*(1), 1-11. doi:10.3758/bf03210552

Sommer, W., Komoss, E., & Schweinberger, S. R. (1997). Differential localization of brain systems subserving memory for names and faces in normal subjects with event-related potentials. *Electroencephalography and Clinical Neurophysiology*, *102*(3), 192-199. doi:10.1016/s0013-4694(96)95577-0

Sommer, W., Schweinberger, S. R., & Matt, J. (1991). Human brain potential correlates of face encoding into memory. *Electroencephalography and Clinical Neurophysiology, 79*(6), 457-463. doi:10.1016/0013-4694(91)90165-z

Sporer, S. L. (2001). Recognizing faces of other ethnic groups - An integration of theories. *Psychology Public Policy and Law, 7*(1), 36-97. doi:10.1038//1076-8971.7.1.36

Stahl, J., Wiese, H., & Schweinberger, S. R. (2008). Expertise and own-race bias in face processing: an event-related potential study. *Neuroreport*, *19*(5), 583-587.

Stahl, J., Wiese, H., & Schweinberger, S. R. (2010). Learning task affects ERP-correlates of the own-race bias, but not recognition memory performance.

Neuropsychologia, 48(7), 2027-2040. doi:10.1016/j.neuropsychologia.2010.03.024

Steffens, M. C., Landmann, S., & Mecklenbräuker, S. (2013). Participant sexual orientation matters: New evidence on the gender bias in face recognition. *Experimental Psychology, 60*(5), 362-367. doi: 10.1027/1618-3169/a000209

Tanaka, J. W., Curran, T., Porterfield, A. L., & Collins, D. (2006). Activation of preexisting and acquired face representations: The N250 event-related potential as an index of face familiarity. *Journal of Cognitive Neuroscience, 18*(9), 1488-1497. doi:10.1162/jocn.2006.18.9.1488

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology Section A -Human Experimental Psychology*, *46*(2), 225-245. doi:10.1080/14640749308401045

Tanaka, J., Giles, M., Kremen, S., & Simon, V. (1998). Mapping attractor fields in face space: the atypicality bias in face recognition. *Cognition, 68*(3), 199-220. doi:10.1016/s0010-0277(98)00048-1

Tanaka, J. W., Kiefer, M., & Bukach, C. M. (2004). A holistic account of the own-race effect in face recognition: evidence from a cross-cultural study. *Cognition, 93*(1), B1-B9. doi:10.1016/j.cognition.2003.09.011

Tanaka, J. W., & Pierce, L. J. (2009). The neural plasticity of other-race face recognition. *Cognitive Affective & Behavioral Neuroscience, 9*(1), 122-131. doi:10.3758/cabn.9.1.122

Towler, A., White, D., & Kemp, R. I. (2017). Evaluating the Feature Comparison Strategy for Forensic Face Identification. *Journal of Experimental Psychology-Applied*, *23*(1), 47-58. doi:10.1037/xap0000108

Tullis, J. G., Benjamin, A. S., & Liu, X. P. (2014). Self-pacing study of faces of different races: metacognitive control over study does not eliminate the cross-race recognition effect. *Memory & Cognition, 42*(6), 863-875. doi:10.3758/s13421-014-0409-y

Tüttenberg, S. C., & Wiese, H. (in revision). Learning own- and other-race facial identities from natural variability. *Quarterly Journal of Experimental Psychology*.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 43*(2), 161-204. doi:10.1080/14640749108400966

Valentine, T., & Bruce, V. (1986). The effect of race, inversion and encoding activity upon face recognition. *Acta Psychologica, 61*(3), 259-273. doi:10.1016/0001-6918(86)90085-5

Valentine, T., & Endo, M. (1992). Towards an exemplar model of face processing: the effects of race and distinctiveness. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 44*(4), 671-703. doi:10.1080/14640749208401305

Valentine, T., Lewis, M. B., & Hills, P. J. (2016). Face-space: A unifying concept in face recognition research. *Quarterly Journal of Experimental Psychology, 69*(10), 1996-2019. doi:10.1080/17470218.2014.990392

Wan, L. L., Crookes, K., Reynolds, K. J., Irons, J. L., & McKone, E. (2015). A cultural setting where the other-race effect on face recognition has no social-motivational component and derives entirely from lifetime perceptual experience. *Cognition, 144*, 91-115. doi:10.1016/j.cognition.2015.07.011

White, D., Burton, A. M., Jenkins, R., & Kemp, R. I. (2014). Redesigning Photo-ID to Improve Unfamiliar Face Matching Performance. *Journal of Experimental Psychology-Applied, 20*(2), 166-173. doi:10.1037/xap0000009

White, D., Kemp, R. I., Jenkins, R., Matheson, M., & Burton, A. M. (2014). Passport Officers' Errors in Face Matching. *Plos One, 9*(8). doi:10.1371/journal.pone.0103510

White, D., Phillips, P. J., Hahn, C. A., Hill, M., & O'Toole, A. J. (2015). Perceptual expertise in forensic facial image comparison. *Proceedings of the Royal Society B-Biological Sciences, 282*(1814), 73-80. doi:10.1098/rspb.2015.1292

Wickens, T. D. (2002). *Elementary signal detection theory*. Oxford: Oxford University Press.

Wiese, H. (2012). The role of age and ethnic group in face recognition memory: ERP evidence from a combined own-age and own-race bias study. *Biological Psychology, 89*(1), 137-147. doi:10.1016/j.biopsycho.2011.10.002

Wiese, H. (2013). Do neural correlates of face expertise vary with task demands? Event-related potential correlates of own- and other-race face inversion. *Frontiers in Human Neuroscience, 7*. doi:10.3389/fnhum.2013.00898

Wiese, H., Kaufmann, J. M., & Schweinberger, S. R. (2014). The Neural Signature of the Own-Race Bias: Evidence from Event-Related Potentials. *Cerebral Cortex, 24*(3), 826-835. doi:10.1093/cercor/bhs369

Wiese, H., & Schweinberger, S. R. (2018). Inequality between biases in face memory: Event-related potentials reveal dissociable neural correlates of own-race and own-gender biases. *Cortex, 101*, 119-135. doi:10.1016/j.cortex.2018.01.016

Wiese, H., Stahl, J., & Schweinberger, S. R. (2009). Configural processing of other-race faces is delayed but not decreased. *Biological Psychology, 81*(2), 103-109. doi:10.1016/j.biopsycho.2009.03.002

Wiese, H., Tüttenberg, S. C., Ingram, B. T., Chan, C. Y. X., Gurbuz, Z., Burton, A. M., & Young, A. W. (in press). A Robust Neural Index of High Face Familiarity. *Psychological Science*. doi:10.1177/0956797618813572

Wirth, B. E., & Carbon, C. C. (2017). An Easy Game for Frauds? Effects of Professional Experience and Time Pressure on Passport-Matching Performance. *Journal of Experimental Psychology-Applied, 23*(2), 138-157. doi:10.1037/xap0000114

Wolff, N., Kemter, K., Schweinberger, S. R., & Wiese, H. (2014). What drives social in-group biases in face recognition memory? ERP evidence from the own-gender bias. *Social Cognitive and Affective Neuroscience, 9*(5), 580-590. doi: 10.1093/scan/nst024

Woodward, A. E., & Bjork, R. A. (1971). Forgetting and remembering in free recall: Intentional and unintentional. *Journal of Experimental Psychology, 89*(1), 109-116. doi:10.1037/h0031188

Wuttke, S. J., & Schweinberger, S. R. (2019). The P200 predominantly reflects distance-to-norm in face space whereas the N250 reflects activation of identity-specific representations of known faces. *Biological Psychology, 140,* 86-95. doi:10.1016/j.biopsycho.2018.11.011

Wright, D. B., & Sladden, B. (2003). An own gender bias and the importance of hair in face recognition. *Acta Psychologica, 114*(1), 101-114. doi: 10.1016.S0001-6918(03)00052-0

Yan, X. Q., Andrews, T. J., Jenkins, R., & Young, A. W. (2016). Cross-cultural differences and similarities underlying other-race effects for facial identity and expression. *Quarterly Journal of Experimental Psychology, 69*(7), 1247-1254. doi:10.1080/17470218.2016.1146312

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81*(1), 141-&. doi:10.1037/h0027474

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language, 46*(3), 441-517. doi:10.1006/jmla.2002.2864

Young, A. W., & Burton, A. M. (2018). Are We Face Experts? *Trends in Cognitive Sciences, 22*(2), 100-110. doi:10.1016/j.tics.2017.11.007

Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configural information in face perception. *Perception, 16*(6), 747-759. doi:10.1068/p160747

Young, S. G., Bernstein, M. J., & Hugenberg, K. (2010). When do own-group biases in face recognition occur? Encoding versus post-encoding. *Social Cognition, 28*(2), 240-250. doi:10.1521/soco.2010.28.2.240

Young, S. G., & Hugenberg, K. (2012). Individuation Motivation and Face Experience Can Operate Jointly to Produce the Own-Race Bias. *Social*

Psychological and Personality Science, 3(1), 80-87. doi:10.1177/1948550611409759

Young, S. G., Hugenberg, K., Bernstein, M. J., & Sacco, D. F. (2012). Perception and Motivation in Face Recognition: A Critical Review of Theories of the Cross-Race Effect. *Personality and Social Psychology Review, 16*(2), 116-142. doi:10.1177/1088868311418987

Yovel, G., & Paller, K. A. (2004). The neural basis of the butcher-on-the-bus phenomenon: when a face seems familiar but is not remembered. *Neuroimage, 21*(2), 789-800. doi:10.1016/j.neuroimage.2003.09.034

Zhao, L., & Bentin, S. (2008). Own- and other-race categorization of faces by race, gender, and age. *Psychonomic Bulletin & Review, 15*(6), 1093-1099. doi:10.3758/pbr.15.6.1093

Zhao, M. T., Hayward, W. G., & Bulthoff, I. (2014). Holistic processing, contact, and the other-race effect in face recognition. *Vision Research, 105*, 61-69. doi:10.1016/j.visres.2014.09.006

Zhou, X., Matthews, C. M., Baker, K. A., & Mondloch, C. J. (2018). Becoming Familiar With a Newly Encountered Face: Evidence of an Own-Race Advantage. Perception. doi:10.1177/0301006618783915

Zhou, X. M., & Mondloch, C. J. (2016). Recognizing "Bella Swan" and "Hermione Granger": No Own-Race Advantage in Recognizing Photos of Famous Faces. *Perception, 45*(12), 1426-1429. doi:10.1177/0301006616662046

Zimmermann, F. G. S., & Eimer, M. (2013). Face learning and the emergence of view-independent face recognition: An event-related brain potential study.

Neuropsychologia, 51(7), 1320-1329. doi:10.1016/j.neuropsychologia.2013.03.028

Zimmermann, F. G. S., & Eimer, M. (2014). The activation of visual memory for facial identity is task-dependent: Evidence from human electrophysiology. *Cortex, 54*, 124-134. doi:10.1016/j.cortex.2014.02.008